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FINAL
REMEDIAL INVESTIGATION REPORT
VOLUME I

BERKS SAND PIT
SUPERFUND SITE
LONGSWAMP TOWNSHIP, PENNSYLVANIA

Submitted to

PENNSYLVANIA DEPARTMENT OF ENVIRONMENTAL RESOURCES
Harrisburg, Pennsylvania

Submitted by

BAKER/TSA, INC.
Coraopolis, Pennsylvania

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EXECUTIVE SUMMARY

This draft report documents the Remedial Investigation (RI) activities undertaken at the Berks Sand Pit Site, a Superfund Site located in Berks County, Pennsylvania. The investigation was conducted to collect and evaluate environmental data in order to define conditions at the site. The RI was accomplished by examining the type, magnitude, and extent of contamination originating from the sand pit area.

The Berks Sand Pit originally was created by the removal of sand and gravel from the area and reportedly was used by area residents for refuse disposal. Industrial waste also was assumed to have been disposed of at this site. Houses were constructed and private wells installed at this location beginning in 1978, after the pit was backfilled. During January 1982, groundwater contamination was observed in the area, and despite emergency actions taken by the EPA, little contamination was discovered even though the pit was partially excavated, and later backfilled with clean fill.

Due to public concern regarding possible groundwater pollution related to contaminants from the sand pit, U. S. EPA Region III and PADER were requested to assess the situation. Site conditions were evaluated via the Hazard Ranking System (HRS) and the site was found to be eligible for inclusion on the National Priorities List (NPL).

The sampling results and subsequent risk assessment revealed that the only mediums that exhibited concentrations of contaminants above background levels were the groundwater and some of the surface sampling locations. Evaluation of the analytical data suggests that off-site contamination has probably resulted from previous disposal activities in the area around the sand pit. Concentrations of contaminants that pose a health threat, due to ingestion of drinking water, were encountered in water samples obtained from some residential and monitoring wells.

A Feasibility Study (FS), based on the results of the RI, will be conducted to identify technically feasible, cost-effective, and environmentally sound remedial action alternatives. These alternatives will be evaluated and the most appropriate action selected for implementation at the Berks Sand Pit Site.

INTRODUCTION

1.0 INTRODUCTION

This Remedial Investigation (RI) Report presents the field investigations and analytical results obtained from the site investigation performed at the Berks Sand Pit Site, located in Longswamp Township, Pennsylvania (See Figure 1-1). The RI was performed in order to compile and evaluate environmental data and to define conditions at the site. Environmental data were collected in order to examine the types, magnitude, and extent of suspected contamination originating from the sand pit area. Then, based on an assessment of this information, objectives and criteria for evaluating potential remedial actions as well as a preliminary list of alternative corrective measures were developed. These efforts serve as the basis for performing the Feasibility Study (FS), which will be conducted to examine alternatives and recommend a technically feasible, cost-effective, and environmentally sound remedial action to be implemented at the Berks Sand Pit Site.

The Remedial Investigation field investigation tasks conducted during the Berks Sand Pit project were performed in a logical sequence to collect information relevant to the site and address the extent and nature of contamination at the Berks Sand Pit Site. Data generated during the execution of the field method provided the information necessary to evaluate the site conditions so the formulation of a remedial action plan can be prepared during the FS stage of the project.

1.1 Authorization

This project is being performed for the Pennsylvania Department of Environmental Resources in accordance with our engineering agreement of April 19, 1987. This agreement has been amended twice (Technical Amendment No. 1, dated May 22, 1987 and No. 2, dated October 2, 1987) in order to provide additional site investigation services.

1.2 Purpose

The purpose of the Remedial Investigation is to gather information through site investigation and laboratory analysis activities in order to characterize the site so that the nature and extent of contamination can be defined. This information subsequently was used to prepare a risk assessment, which describes the public health and environmental risks posed by contamination associated with the site.

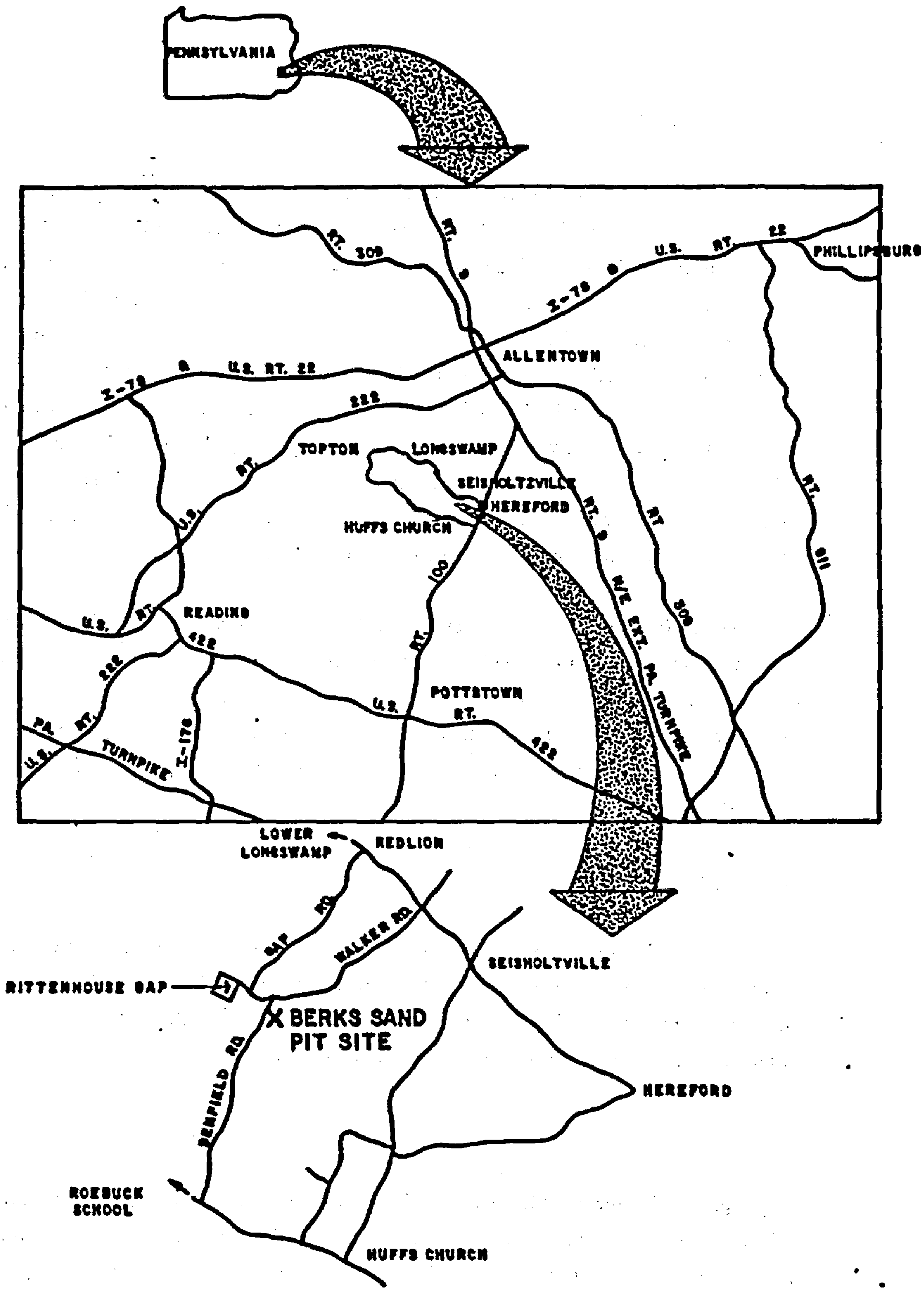


FIGURE 1-1
BERKS SAND PIT SITE
PROJECT LOCATION MAP

AR300012

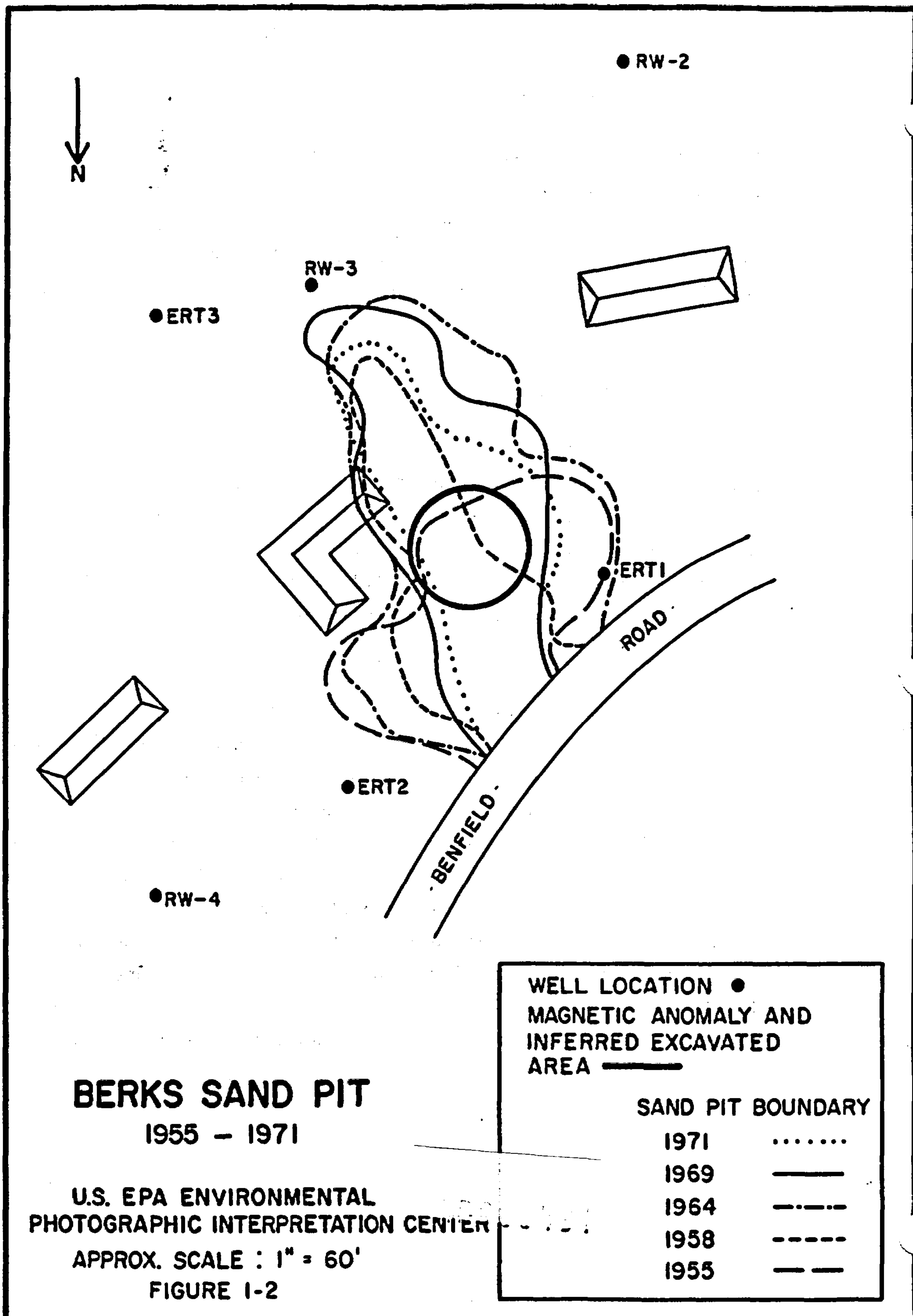
1.3 Problem Statement

Uncontrolled and undocumented dumping of hazardous materials, primarily chlorinated solvents, has caused the underlying fractured bedrock to become contaminated. Residents rely on this water as their sole source of drinking water and, therefore, are at risk through this exposure route. Surface evidence of the disposal does not exist, but the results of laboratory analyses have indicated that the wastes are encountered within the fractured bedrock below the site.

1.4 Site Background Information

The Berks Sand Pit site is located in Longswamp Township, Berks County, Pennsylvania (Figure 1-1). The site is approximately 15 miles northeast of Reading, near the Village of Huffs Church. A review of area geologic mapping reveals the site to be located within the Reading Prong Section of the New England Physiographic Province. The Reading Prong is characterized by Precambrian crystalline bedrock of several lithologies. Water wells generally are set in the upper portion of bedrock where joint fractures allow for above average yield.

The Berks Sand Pit originally was created by the removal of sand and gravel from the area. The size of the pit was approximately 100 feet in diameter and 30 feet deep. The pit reportedly was used by area residents for refuse disposal. Industrial waste also was alleged to have been disposed of in the area around the pit. Houses were constructed and private wells installed at this location beginning in 1978, after the pit was backfilled. During January 1982, groundwater contamination was detected in the area by the residents, and despite emergency actions taken by EPA, no contaminant was discovered even though the pit was partially excavated and backfilled with clean fill (Figure 1-2). Groundwater contamination persists to this day, as indicated by elevated levels of organic compounds such as 1,1,1-trichloroethane and 1,1-dichloroethene. The predominant organic contaminant at the site is 1,1,1-trichloroethane and is being used as an indicator of relative concentrations of other organic compounds.



BERKS SAND PIT
1955 – 1971

U.S. EPA ENVIRONMENTAL PHOTOGRAPHIC INTERPRETATION CENTER
APPROX. SCALE : 1" = 60'
FIGURE 1-2

AR300014

1.5 Site History

Rittenhouse Gap, approximately one-fourth of a mile northwest of the site, has been extensively mined for magnetite iron ore and is believed to be one of the oldest ore-producing districts in Berks County. The now abandoned iron mines consisted of open cuts, tunnels, and shafts. The cuts generally are elongated northeastward following the strike of the ore body while shafts and tunnels dip steeply southeastward. The Cha Gery mine shaft is located approximately 1,200 feet to the west of the intersection of Benfield and Walker Roads.

Sand and gravel quarrying took place in the area known as the sand pit. The property was used as a borrow area and reportedly was approximately 30 feet deep by 100 feet in diameter.

Residents reported tank trucks traveling Benfield Road between September and November 1981, and that shortly thereafter, in early 1982, their well water had a distinguishable odor and obnoxious taste. Laboratory analysis conducted by PADER indicated that the following chemicals were detected in the residential well RW-3:

1,1,1-Trichloroethane	> 45,000 µg/l
1,1-Dichloroethene	> 800 µg/l
1,1-Dichloroethane	> 300 µg/l
Dichloromethane	> 300 µg/l
1,2-Dichloroethane	> 150 µg/l
Toluene	> 150 µg/l

The EPA conducted a cleanup effort in the area of the pit during the summer of 1983. Activities consisted of excavating the area reported to be the sand pit and also installing a water supply well for four families whose wells were contaminated by the previous disposal operations. The excavation did not encounter any buried drums or other objects relating to the contamination.

1.6 Nature and Extent of Problem

The primary risk associated with the previous disposal of wastes at the Berks Sand Pit Site is the degradation of groundwater quality. The public health hazards associated with the disposal operations result from exposure to contaminants in the groundwater through use as potable water. To date, contamination in four residential wells has been detected above the National Primary Drinking Water Standards (NPDWS).

The contaminants, primarily solvents, have infiltrated into the groundwater system and thereby entered the potable water supply. Due to the highly irregularly fractured nature of the bedrock, the contaminants have dispersed to various degrees in a vertical and horizontal direction. Geologic investigations have indicated that fractured bedrock was encountered at depths greater than 250 feet. Continued use of the groundwater by residents not yet affected by the contaminants may have enhanced movement of the chemicals and increased the area affected.

1.7 Remedial Investigation Summary

The first step in the Remedial Investigation consisted of collecting and reviewing pertinent data from federal, state, and local agencies including the U. S. Environmental Protection Agency (EPA), PADER, and various Berks County agencies. After site access was obtained, a detailed site reconnaissance was performed to familiarize personnel with the site, locate potential hazards, identify key physical features, sample residential wells, and conduct a soil gas survey to locate possible soil contamination.

A site operation manual was developed that outlined the methods to be followed to gather environmental data (air, surface water, sediments, subsurface soils, and groundwater) along with a site specific health and safety plan to be followed during the course of field activities, a contingency plan, a contaminated materials handling plan, and a quality assurance/quality control plan.

Following these preliminary activities, an extensive field sampling plan was conducted. The sampling was performed to: 1) determine the areal extent of contamination, 2) determine groundwater quality, 3) provide additional subsurface information, and 4) evaluate surface water and local well water quality off site. On-site activities included air monitoring, surface and borehole geophysical surveys, pump tests, sampling of surface waters and local residential water supplies, subsurface soils, and groundwater from the newly installed monitoring wells. A second round of groundwater sampling and composite samples of RI-generated wastes were also taken. Ancillary field activities employed for the RI included site surveying and mapping, in order to provide a current map of the site, and air monitoring to determine levels of respiratory protection requirements for the site. Highlighted below are the dates and events that pertain to the Berks Sand Pit Site Field Investigation.

Based on the site reconnaissance and discussions with PADER, the sampling locations (shown on Drawing 1) were chosen to provide the information necessary to characterize the site conditions. The following lists the samples collected for each sampling event:

<u>May 1987 - Site Reconnaissance</u>

1. Air Quality Monitoring
2. Soil Gas Survey
3. Residential Wells

<u>Fall 1987 - Groundwater Sampling Round</u>

1. Air Quality Monitoring
2. Surface Water
3. Subsurface Soil Samples
4. Groundwater Monitoring Well Samples (Deep)

<u>Winter 1988 - Second Sampling Round</u>

1. Air Quality Monitoring
2. Surface Water
3. Groundwater Monitoring Well (Deep)
4. Groundwater Monitoring Well (Shallow)
5. Residential Wells
6. Water Supply Wells

The specific sampling and quality control procedures followed during the RI field investigation are contained in the Operations Plan.

Due to the possibility of encountering hazardous conditions, safety procedures were developed and enforced through the implementation of a site Health and Safety Plan (HASP). The HASP was followed to throughout all on-site activities to protect the RI field team. A briefing was given to the on-site personnel as to the possible hazardous contaminants that could be encountered, personal protection available, location of nearest phone and first aid kit, and directions to the nearest hospital. In case of an emergency, phone numbers and directions to the nearest hospital were posted at all times in the project trailer. The Site Health and Safety Officer was charged with the responsibility of enforcing the HASP during the field program.

The level of personal protection selected for the site was determined to be Level D (the lowest level of protection) for initiation of the field activities. Standard issue steel-toed boots, hard hats, and safety glasses were worn throughout the drilling operations. Other safety equipment such as rubber overboots, tyvek coveralls, nitrile gloves, and cartridge respirators were kept in the project trailer and worn when deemed necessary by the On-Site Coordinator and Site Health and Safety Officer. Periodic direct readout air monitoring for organic vapors was conducted in addition to performing quantitative air sampling for both organics and metals at specified intervals in order to verify respiratory protection requirements.

Once the field investigation was completed, the next step was to compile and evaluate field investigation analytical results in order to identify the magnitude and extent of contaminants and the existing conditions in which the contaminants reside. Inherent in this evaluation was an assessment of the reliability of the data through validation procedures. The review process included comparing the data with applicable standards. Then an evaluation was made as to the extent of potential threats to human health and the environment. This report outlines the background information leading up to the remedial investigation, the field methods employed during the investigation, the analytical results, and the ensuing discussion of analytical results.

1.8 Overview of Report

The Remedial Investigation report has been prepared in accordance with the EPA Document "Guidance on Remedial Investigations Under CERCLA" (June 1985). The RI report consists of the following major sections. The "Site Features/Environmental Setting" chapter focuses on the demography, land use, environmental setting, climatology, geology, and hydrogeology associated with the Berks Sand Pit Site. The information in this chapter was collected by reviewing literature pertinent to the project and contacting federal, state, and local authorities on the specific subject matter. The next chapter on "Geological, Hydrogeological, and Geophysical Investigations" contains information obtained from a review of available geologic publications and information obtained from the various site investigations.

Information and data presented in the first three chapters is the foundation for the chapter "Nature and Extent of Contamination." The lateral and vertical extent of contamination is defined to the extent possible, for air, surface water, groundwater, and subsurface soils. The next chapter, "Public Health Evaluation and Environmental Concerns" relies on the contents of the previous chapter in order to serve as a basis for the risk assessment. This chapter identifies the exposure potential and pathways of contamination and also identifies the potential receptors. This chapter also presents the results of quantifying the risks as related to the public and environmental concerns.

1.9 Data Validation

Laboratory analysis was performed by the four laboratories identified in Table 1-1. The analytical procedures were performed in accordance with EPA's Contract Laboratory Program (CLP) and the analytical procedures listed in 40 CFR 136. Those laboratories and the analysis they performed are identified below.

Table 1-1

LABORATORY ANALYSIS

Laboratory	Air	Soil	Surface Water and Groundwater
NUS	●	●	●
Compuchem		●	●
Zenon			●
Pace			●

All data received from the laboratories were reviewed and validated by Baker/TSA staff and Free-Col Laboratories. The validation process involves the examination of quality control data provided by the contract laboratory to determine if quality assurance protocols were followed and the analytical results are meaningful. The procedures followed by validating organic, pesticide, PCB, and inorganic data for this project were outlined by U. S. EPA Region III in order to establish standard quality assurance review of laboratory performance.

SITE FEATURES

2.0 SITE FEATURES/ENVIRONMENTAL SETTING

2.1 Demography

The Berks Sand Pit Site is located in Longswamp Township, which is near the eastern corner of Berks County, Pennsylvania. The site is approximately 15 miles east-northeast of Reading, and 20 miles west-southwest of Allentown. This largely rural township has a population of about 170 persons per square mile. The 1980 Census population for Longswamp Township was 4,627. The 1986 population estimate was 4,610. Although these figures show a slight decline, the population is expected to increase as housing development increases in Longswamp Township. Projections estimate that the population will be 5,377 persons in 1990 and 6,395 persons in 2000.

2.2 Land Use

The Berks Sand Pit originally was created by the removal of sand and gravel from the area and allegedly later was used by residents for refuse disposal. Industrial waste also was likely to have been disposed of at this site. Houses were constructed and private wells installed at this location beginning in 1978, after the pit was backfilled. The sand pit is located on what is now the Van Elswyck property.

Rittenhouse Gap has been mined extensively for magnetic iron ore and is believed to be one of the oldest ore-producing districts in the United States. According to local residents, mining reportedly took place prior to 1785 and continued until the last generation. The shaft of one mine, Cha Gery Mine, is located approximately 1200 feet to the west of the Van Elswyck property.

Currently, two important land uses near the site are agricultural and residential development. Fields and orchards are located nearby in Longswamp Township, as well as in neighboring Hereford and District Townships. The property the site is located on and the property in the immediate vicinity of the site is zoned as "R-2," which denotes a low density, residential district.

The main recreational use of the land in Longswamp Township is fishing and hunting. The Berks Sand Pit area is drained by the headwaters of three creeks: West Branch of [illegible] Creek, Perkiomen Creek and Swabia Creek. These creeks are all classified for cold water fishes and trout stocking. Ring-necked pheasants are the most abundant small game species in Berks County, while cottontail rabbits are the second most abundant. White-tailed deer also are plentiful. In addition to the hunting and fishing in Berks County, approximately four miles northeast of the site is the Doe Mountain Recreation Area in Lehigh County. Located in Lower Macungie Township, this ski area has a season that runs from about mid-December until mid-March.

2.3 Environmental Concerns

Visual evidence of environmental damage was not encountered during the Remedial Investigation. One case of vegetative stress, a brown spot of grass on the lawn of the Van Elswyck property, was investigated. Extensive soil sampling showed that the discoloration was unrelated to the contamination at the site. The West Branch of the Perkiomen Creek, which is heavily used and supports trout, was identified as a potential receptor. No impact to the stream was detected. A more complete treatment of the environmental risks of this site is provided in Section 6.0 "Public Health Evaluation and Environmental Concerns."

2.4 Climatology

The climate in the area is mild, humid, with well-defined seasons. Temperatures usually are moderate. Precipitation is generally ample and dependable with the greatest amounts falling during the summer months. The annual temperature and precipitation for the area is 51.0°F and 44.31 inches, respectively. The prevalent wind direction is from the west with an average speed of 9.2 miles per hour. The region is not prone to destructive storms of large extent, although heavy thunderstorms and tornadoes may affect limited areas. The growing season ranges from 170 days to 185 days, with an average length of 177 days. Periods of drought lasting long enough to cause crop damage occur approximately once every 10 years (Source: NOAA, 1985 for Allentown, Pennsylvania).

2.5 Geology

The Berks Sand Pit Site is located in a portion of the Reading Prong in Eastern Pennsylvania. The Reading Prong is a southern extension of the New England Physiographic Province and is bounded on the north and south by major faults (1). To the north of the Reading Prong lies the Great Valley Region of the Valley and Ridge Province; the Triassic Lowlands Region of the Piedmont Province lies to the south.

The lithologies of the Reading Prong consist of metamorphosed igneous, sedimentary, and volcanic rocks of Precambrian and Cambro-ordovician age; primarily gneisses, granites, limestones, dolomite, marble, and quartzite (2). The major geologic structures underlying the Berks Sand Pit Site consists primarily of highly fractured and weathered Precambrian granitic gneiss. Disseminated magnetite occurs throughout the area. Massive magnetite deposits also are common.

Fractures, joints, and foliations in the area strike in a northeasterly direction with moderate to steep dips. Fracture trace analyses indicate that there also is a conjugate set of northwesterly striking fractures.

The granitic gneiss is highly weathered throughout the area and the depth of competent bedrock is variable. There is, in general, no distinct boundary between the overburden, which includes soils, saprolite, and highly weathered rock and competent bedrock. Rather, there is a gradational change from saprolite to competent, unweathered bedrock. In general, the saprolite is a light brown, tan to orange clay with some silt and sand, and quartz and feldspar pebbles grading to sand and clay with quartz and gneiss fragments at depth. Some local zones near the bedrock show evidence of foliation and relict structures.

2.6 Hydrogeology

Groundwater in the Berks Sand Pit Site area is encountered in both the overburden, which includes the saprolite and highly weathered bedrock, and in the fractured, unweathered bedrock. The overburden is variably saturated. There appears to be both perched water table zones and unconfined and confined conditions. Generally, the perched zones occur above clay and silt layers in the saprolite and weathered rock. Both confined and unconfined zones occur in the weathered rock. The bedrock, a granitic gneiss, has a low primary porosity and permeability but has a significant secondary porosity and permeability due to the presence of a complex fracture system. The fractures and fractured zones provide preferred avenues for groundwater movement. Other avenues for groundwater movement include faults, mineralogical changes and grain size changes.

The amount of water that moves through the bedrock depends on the hydraulic gradient and the hydraulic conductivity of the fractures. The hydraulic conductivity of the fractures depends on such properties as frequency of occurrence, orientation, dimensions, interconnectedness, filling material, etc. These properties are quite variable and as a result, a highly complex flow field has developed at the site. In general, there are a large number of interconnected fractures oriented in a northwesterly direction.

The primary orientation of planar features in the Reading Prong is to the northeast and a regional hydraulic gradient has developed in this direction (1, 4, 5). The gradient at the site also is to the northeast. There may be local deviations from the regional gradient though, due to structural variations and/or the effects of local pumping (5). Domestic pumping rates, however, are usually quite low and these generally have little effect on the gradient. On the other hand, pumping for agricultural purposes may have a significant effect on the gradient. The local groundwater flow patterns tend to be quite complex due to these fractures.

Well yields in the crystalline rocks of the Reading Prong are generally low (5 gpm to 15 gpm) though higher yields may be encountered in highly weathered zones or along fractures (5, 6).

2.7 Hydrology

The Berks Sand Pit Site is located near the divides of three small watersheds: West Branch of Perkiomen Creek, Perkiomen Creek, and Swabia Creek. The headwaters of the West Branch of Perkiomen Creek and of Perkiomen Creek are shown in Plate 1. The West Branch of Perkiomen drains an area east of Benfield Road and south of Walker Road. Perkiomen Creek drains an area west of Benfield Road and south of Walker Road. Swabia Creek drains an area north of Walker Road and west of Gap Road.

Both Perkiomen and the West Branch of Perkiomen Creek flow approximately southeast. Waters for these streams are derived from springs, seeps, and from surface runoff. The confluence of these two watercourses is approximately one-half to one mile southeast of the site near the town of Huffs Church.

Swabia Creek generally flows northeast. Waters for this watercourse area also are derived from springs, seeps, and surface runoff.

Surface slopes in the vicinity of the site are generally shallow to moderate (0 to 12 percent). Slopes to the west of Gap Road are moderate to steep.

2.8 Soils

A soil survey of Berks County was performed between 1947 and 1964 by U. S. Department of Agriculture, Soil Conservation Service (SCS). The soils in the southern half of Longswamp Township are from the Chester-Glenville-Brandywine Association. This association is typified by deep and moderately deep, well-drained and moderately well-drained, rolling to hilly soils. These soils are formed in material weathered from granite gneiss and other igneous or metamorphoses rocks on Rending Hills and South Mountain. The native soils from the site are from the Chester soil series.

The predominant soils at the site, according to the U. S. Department of Agriculture Soil Survey of Berks County (10) are the Chester channery silt loam (ChB2) and the Chester very stony silt loam (CnB). These are deep, well drained soils formed from material weathered from granitic gneiss and underlain by sandy saprolite. It should be noted that the C horizon (greater than approximately 3.6 feet deep) of the Chester series has "many manganese and iron films on ped surfaces" (10). In general, soils are well drained and have a moderately high permeability (approximately 10 gpd/ft^2 to 30 gpd/ft^2).

2.9 Mining Activity

Rittenhouse Gap is believed to be one of the oldest ore-producing districts in Berks County, and has been extensively mined for magnetite. Other materials mined in the county include hematite, clay, ochre, graphite, and umber. According to local residents, mining took place prior to 1785 and continued into the last generation. The now abandoned mines consisted of open cuts, tunnels, and shafts. The cuts are generally elongated northeastward following the strike of the ore body while shafts and tunnels dip steeply southeastward.

A mine of particular concern is named the Cha Gery Mine and is located approximately 1,200 feet to the west of the sand pit. This mine shaft was sunk in 1864 to a depth of 70 feet at a dip 85° southeast. The shaft later was extended 30 feet, and was abandoned in 1881. Apparently, the mine shaft received a considerable amount of water as it required pumping equipment.

GEOLOGY

3.0 GEOLOGICAL, HYDROGEOLOGICAL AND GEOPHYSICAL INVESTIGATIONS

An extensive field investigation was conducted in the vicinity of the Berks Sand Pit Site to characterize the geology, hydrogeology, and the nature and extent of contamination in the air, soil atmosphere, soil, surface water and sediments, and groundwater. This chapter provides a general description of the regional geology, an account of the reconnaissance and field activities, and a summary of the site geology and hydrogeology. The nature and extent of contamination is discussed in detail in Section 5.0.

3.1 Regional Geology and Hydrogeology

The Berks Sand Pit Site is located in a portion of the Reading Prong in Eastern Pennsylvania. The Reading Prong is a southern extension of the New England Physiographic Province and is bounded on the north and south by major faults (1). To the north of the Reading Prong lies the Great Valley Region of the Valley and Ridge Province; the Triassic Lowlands Region of the Piedmont Province lies to the south.

The lithologies of the Reading Prong consist of metamorphosed igneous, sedimentary, and volcanic rocks of Precambrian and Cambro-ordovician age; primarily gneisses, granites, limestones, dolomite, marble, and quartzite (2). Disseminated magnetite occurs in all of these rocks and numerous skarn-type magnetite orebodies of the Cornwall-type occur throughout the Reading Prong. In general, Cornwall-type magnetite ore contains 30 percent to 50 percent iron, 1 percent to 2 percent sulfur as pyrite or chalcopyrite and approximately 15 percent silica as actinolite, diopside, phlogopite, chlorite, serpentine, and/or talc (3). The ores tend to be low in titanium, have minor amounts of calcite, dolomite, or ankerite, and may have notable amounts of copper and cobalt. (3).

The Reading Prong Section displays a northeast trend. This trend is manifest as north to east trending fractures, fissures and joints, faults, foliations, lithologic contacts, and some topographic features (1, 4). Similar features in the adjacent Great Valley Region also have a north to east trend and, to the north of the Reading Prong is the northeast trending Taconic unconformity -- Blue Mountain Decollement.

The Reading Prong is mostly unglaciated and slopes are generally moderate to steep (2). The Precambrian metamorphic rocks comprise the highlands and Cambro-ordovic[illegible] crop out in the intermontane valleys. The rocks are deeply weathered; overburden thickness ranges from zero to over 50 feet.

The primary porosities and permeabilities of the rocks of the Reading Prong are generally low due to the dense, crystalline nature of the rock. Hence, groundwater occurrence is predominantly in secondary openings such as foliation and/or schistosity planes, fractures, fissures and joints, and faults. The orientation and characteristics (i.e., aperature, filling material, etc.) of these features controls both the amount of groundwater and to some extent the direction of flow. The primary orientation of planar features in the Reading Prong is to the northeast and northwest; a regional hydraulic gradient has developed in a northeasterly direction (1, 4, 5). There may be local deviations from the regional gradient due to structural variations and/or the effects of local pumping (5). Domestic pumping rates, however, are usually quite low and these generally have little effect on the gradient. On the other hand, pumping for agricultural purposes may have a significant effect on the gradient. The local groundwater flow patterns are quite complex and are potentially dependent on extraneous influences.

Well yields in the crystalline rocks of the Reading Prong are generally low (5 gpm to 15 gpm) though higher yields may be encountered in highly weathered zones or along fractures (5, 6).

3.2 Fracture Trace Analysis

A fracture trace analysis was performed to assist in determining the monitoring well locations at the site and to determine likely avenues for groundwater movement. The fracture trace analysis was performed by locating linear features visible on recent aerial photographs. Two types of linear features are potentially visible on aerial photographs (7):

1. A photogeologic fracture trace is a natural linear feature consisting of topographic (including straight stream segments), vegetation, or soil tonal alignments, visible primarily on aerial photographs, and expressed continuously for less than one mile. Only natural linear features obviously not related to outcrop pattern of tilted beds, lineation and foliation, and stratigraphic contacts are classified as fracture traces.

2. A photogeologic lineament is a natural linear feature consisting of topographic (including straight stream segments), vegetation, or soil tonal alignments, visible primarily on aerial photographs or mosaics, and expressed continuously for at least

one mile, but which may be expressed continuously or discontinuously for many miles.

The aerial photographs of the site were checked with a low-magnification stereoscope for these two types of linear features. The linear features were outlined on the photos and were transferred to a base map (see Figure 3-1). The importance of the fracture or lineament traces is that these features are usually underlain by zones of closely spaced fractures or faults in the bedrock. Such zones may be capable of transmitting large quantities of water as compared to the adjacent, less fractured bedrock. At the Berks Sand Pit Site, the primary porosity and permeability of the gneissic bedrock is low; therefore, the ability of the bedrock to transmit water is largely controlled by fractures, fissures, joints, and faults.

After a careful review of the fracture trace analysis, a field reconnaissance was performed to field locate the fracture traces. No surficial evidence of fracture zones was observed southeast of Benfield Road during the field reconnaissance. The only surficial evidence of fracture zones that was observed were the abandoned magnetite mines west and north of the site. The magnetite is thought to be deposited along major fractures in the bedrock. (3) Hence, the magnetite mines may indicate the location and trends of some major fracture zones in the vicinity of the site.

Since it was the intent of the fracture trace analysis to develop a basis for locating the monitoring wells, and since the field location of the fracture traces was completed with only limited success, the monitoring wells were located with respect to the expected location of fracture zones as determined from the aerial photographs. Additional information such as the expected areal distribution of contaminants, the expected groundwater flow direction, and the results of the slam-bar OVA/soil gas survey also were used to locate the nine monitoring wells. Approximate monitoring well locations are shown with respect to the fracture traces on Figure 3-1.

Monitoring wells MW-3, MW-4, MW-5, MW-6 and MW-9 are all located near or along potential fracture zones or lineations downgradient (southeast, east and northeast) of the former sand pit. MW-2 is located near MW-9 along the expected strike of the bedrock. MW-1 is also located near MW-9 but is positioned approximately perpendicular to the expected strike of the bedrock. MW-7 is not necessarily located along a fracture zone but rather it is located directly downgradient from a suspected area of soil contamination on the R-2 property.

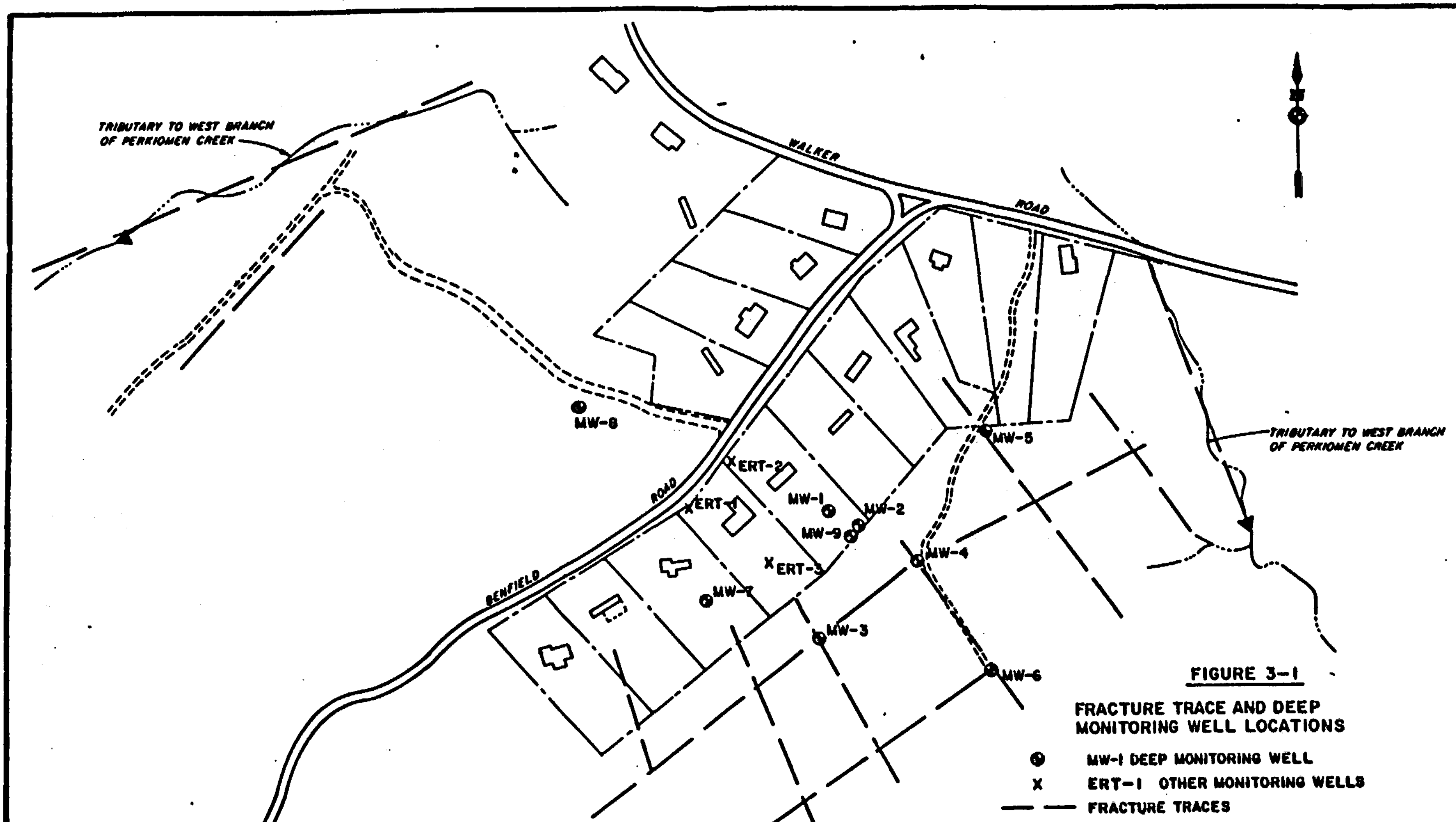


FIGURE 3-1

FRACTURE TRACE AND DEEP MONITORING WELL LOCATIONS

BERKS SAND P.I.T.

N.T.S.

(see Section 3.3). MW-8 is located along a potential westerly flow path downgradient from the former sand pit.

3.3 Soil Gas Survey: Slam-Bar/OVA

A slam-bar soil gas survey was conducted as part of the site reconnaissance to determine the location of near surface organic vapor anomalies. A rectangular grid consisting of 27 sampling points on approximate 200-foot centers was superimposed on the site. Soil gas readings were systematically recorded for each sampling point with the aid of an Organic Vapor Analyzer (OVA). Sampling point locations are illustrated on Drawing 1 and Figure 3-2.

The slam-bars used for this study were constructed from 1-inch I.D. black iron pipe containing 16 1/4-inch holes drilled in the bottom six inches of the pipe.

Prior to sampling, the slam-bars were cleaned with Alconox and water and rinsed with deionized water. The pipe was driven into the soil using an 18-inch fence post driver leaving 18 inches of pipe above ground or until the driving refusal limit of the pipe. The soil in the Berks Sand Pit study area is very rocky and frequently the slam-bar locations were adjusted to allow for the full penetration length, 30 inches, of the slam-bar into the soil.

After the slam-bar was installed, the pipe was hand vacuum pumped for five minutes and an initial OVA reading was taken from the slam-bar. The slam-bar was then allowed to stabilize in the soil for one hour or longer. After the stabilization period, the final OVA reading was taken from the slam-bar. Immediately after the slam-bar was pulled, an OVA reading was taken in the hole generated by the slam-bar.

The background OVA reading for the study area ranged from 2.3 ppm to 2.5 ppm. Most of the sampling stations, SB1 through SB27 (see Table 3-1 and Figure 3-2), had OVA readings near or at background levels. Final ground OVA readings of 1.8 ppm, 0.2 ppm, 0.4 ppm, and 2.5 ppm above background were recorded for SB1, SB10, SB17, and SB21, respectively.

Some contributions to the organic vapor concentrations that were detected above background during the survey may be the result of the slam-bar pipe itself. The sunny and 90°F weather heated the slam-bars as they stabilized in the soil volatilizing some of the residual materials

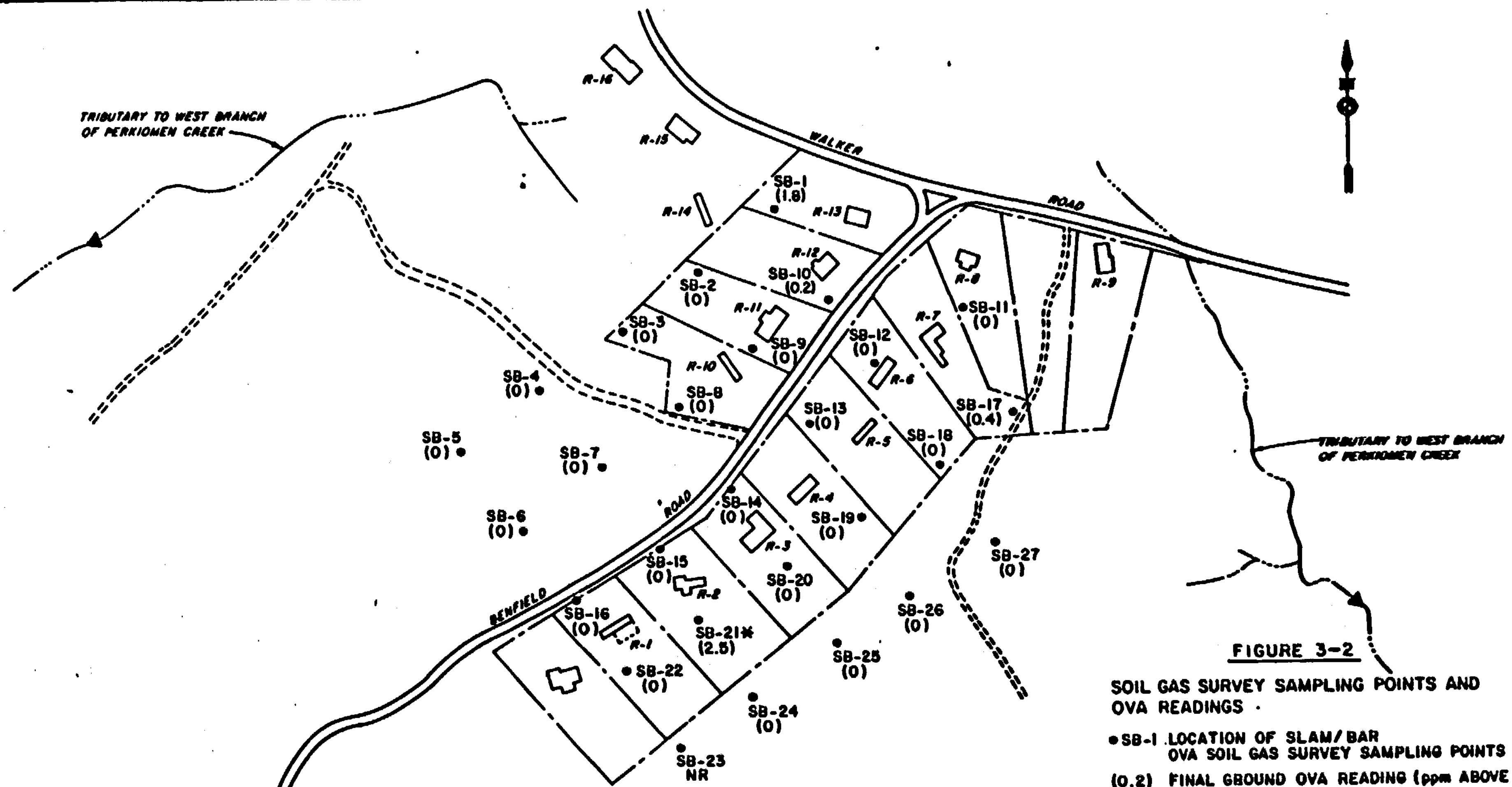


FIGURE 3-2

SOIL GAS SURVEY SAMPLING POINTS AND OVA READINGS

● SB-1	LOCATION OF SLAM/BAR OVA SOIL GAS SURVEY SAMPLING POINTS
(0.2)	FINAL GROUND OVA READING (ppm ABOVE BACKGROUND
R-1	RESIDENTIAL PROPERTY IDENTIFIER
NR	NO READING WAS TAKEN FOR SB-23
*	SEE FIGURE 3-2 FOR SOIL GAS READINGS ADJACENT TO SB-21 AND TABLE 3-1 FOR SOIL GAS READINGS

BERKS SAND P.I.T.

N.T.S.

Table 3-1

BERKS SAND PIT
SLAM-BAR/OVA SOIL GAS SURVEY RESULTS*

Soil Gas Sampling Sites	Depth of Slam-Bar	Date of Survey	Initial Slam-Bar OVA Reading (ppm)	Time of Initial Reading	Final Slam-Bar OVA Reading (ppm)	Final Ground OVA Reading (ppm)	Time of Final Reading
SB1	30"	5-29	0	10:33	0.5	1.8	10:55
SB2	30"	5-29	0	9:43	1.2	0	10:45
SB3	30"	5-28	0	15:28	0	0	9:20
SB4	30"	5-28	0	15:42	0	0	9:25
SB5	30"	5-29	0	16:17	0	0	10:55
SB6	30"	5-29	0	15:58	0	0	10:50
SB7	29"	5-28	0	15:12	0	0	9:15
SB8	30"	5-28	0	14:53	0	0	9:10
SB9	30"	5-29	0	14:07	0	0	15:40
SB10	30"	5-29	0	10:08	2.0	0.2	10:50
SB11	30"	5-29	0	11:41	0.2	0	13:10
SB12	30"	5-29	0.4	13:32	0.2	0	16:00
SB13	30"	5-27	0	11:01	0	0	14:45
SB14	30"	5-27	0	10:30	0	0	14:40
SB15	19"	5-27	0	14:35	0	0	15:55
SB16	30"	5-27	0	11:57	0	0	14:55
SB17	30"	5-29	0	11:56	0.3	0.4	13:15
SB18	30"	5-29	0	13:58	0	0	15:35
SB19	30"	5-27	0	15:07	0	0	16:00
SB20	30"	5-27	0	11:35	0	0	14:50

* All OVA readings are reported as above background readings.

Table 3-1

BERKS SAND PIT
SLAM-BAR/OVA SOIL GAS SURVEY RESULTS*
-continued-

Soil Gas Sampling Sites	Depth of Slam-Bar	Date of Survey	Initial Slam-Bar OVA Reading (ppm)	Time of Initial Reading	Final Slam-Bar OVA Reading (ppm)	Final Ground OVA Reading (ppm)	Time of Final Reading
SB21	30"	5-28	0	10:27	3.0	2.5	14:15
SB21-A	36"	5-30	2.0	11:23	1.6	1.6	12:30
SB21-B	30"	5-30	0.6	11:39	1.2	0.8	12:35
SB21-C	30"	5-30	0	11:56	1.2	0.3	12:40
SB21-D	30"	5-30	0	13:18	2.0	0	14:20
SB21-E	22"	5-30	0	13:52	0.2	0	14:25
SB21-F	37"	5-30	0	14:00	0.2	0	14:30
SB21-G	30"	5-30	6.2	15:00	3.0	10.0	16:00
SB22	12"	5-29	0	16:35	0	0	17:00
SB23(1)							
SB24	30"	5-28	0	10:45	0	0	14:20
SB25	30"	5-28	0	11:01	0	0	14:25
SB26	30"	5-28	0	11:21	0	0	14:30
SB27	30"	5-28	0.4	11:54	0.2	0	14:35

* All OVA readings are reported as above background readings.

(1) No data was recorded for SB23.

in or on the pipe. The OVA reading for the pipe itself, when heated, registered approximately 0.6 ppm above background.

Significant OVA readings were detected at Stations SB21, SB21-A and SB21-G (Figure 3-3). The final ground OVA level at Station SB21 was 2.5 ppm above background. Station SB21-A had levels of 1.8 ppm above background and SB21-G had the highest detected concentrations at 6.2 ppm, 3.0 ppm, and 10.0 ppm, above background for initial, final slam-bar, and final ground OVA measurements, respectively. The needle on the OVA meter was steady at these higher levels. Station SB21-G is located in a shallow depression near the tree line on the R-2 property. The dimensions of the depression are approximately 8 inches x 24 inches x 2 inches.

The apparent soil gas anomaly in the vicinity of SB21 was further investigated by placing eight test borings (LTB1 through LTB6, TB-10, and TB-11) on the R-2 property and by placing monitoring well MW-7 immediately downgradient from SB21-G (see Section 3.5).

3.4 Surface Water and Sediment Sampling

A surface water and sediment sampling program was initiated to identify any contamination in local, potentially downgradient surface waters. Surface water samples were collected at 13 springs, seeps, mine pools, and/or water courses. Sediment samples also were taken to give an indication of possible chronic contamination. The locations of SP surface water and sediment sampling points are shown in Drawing 1 and Figure 3-4; Table 3-2 gives summary descriptions of the sampling points.

Sampling points SP-1 through SP-8 are located east and downgradient from the former sand pit. SP-1, SP-2, SP-4, and SP-5 are seeps that form the headwaters of the West Branch of the Perkiomen Creek; SP-3 is a spring. SP-6, SP-7 and SP-8 are stream sampling points in the headwaters of the West Branch of the Perkiomen Creek.

Sampling point SP-9 is a mine pool located in the former shaft of the Cha Gery Mine west-northwest of the former sand pit. Even though SP-9 is generally downgradient from the former sand pit, it was included to account for possible secondary flow paths and to confirm that the Cha Gery Mine is not a source or receptor of contamination.

Sampling points SP-10 and SP-11 are stream sampling points and SP-12 is a spring forming the headwaters of a tributary to the West Branch of Perkiomen Creek, southwest to

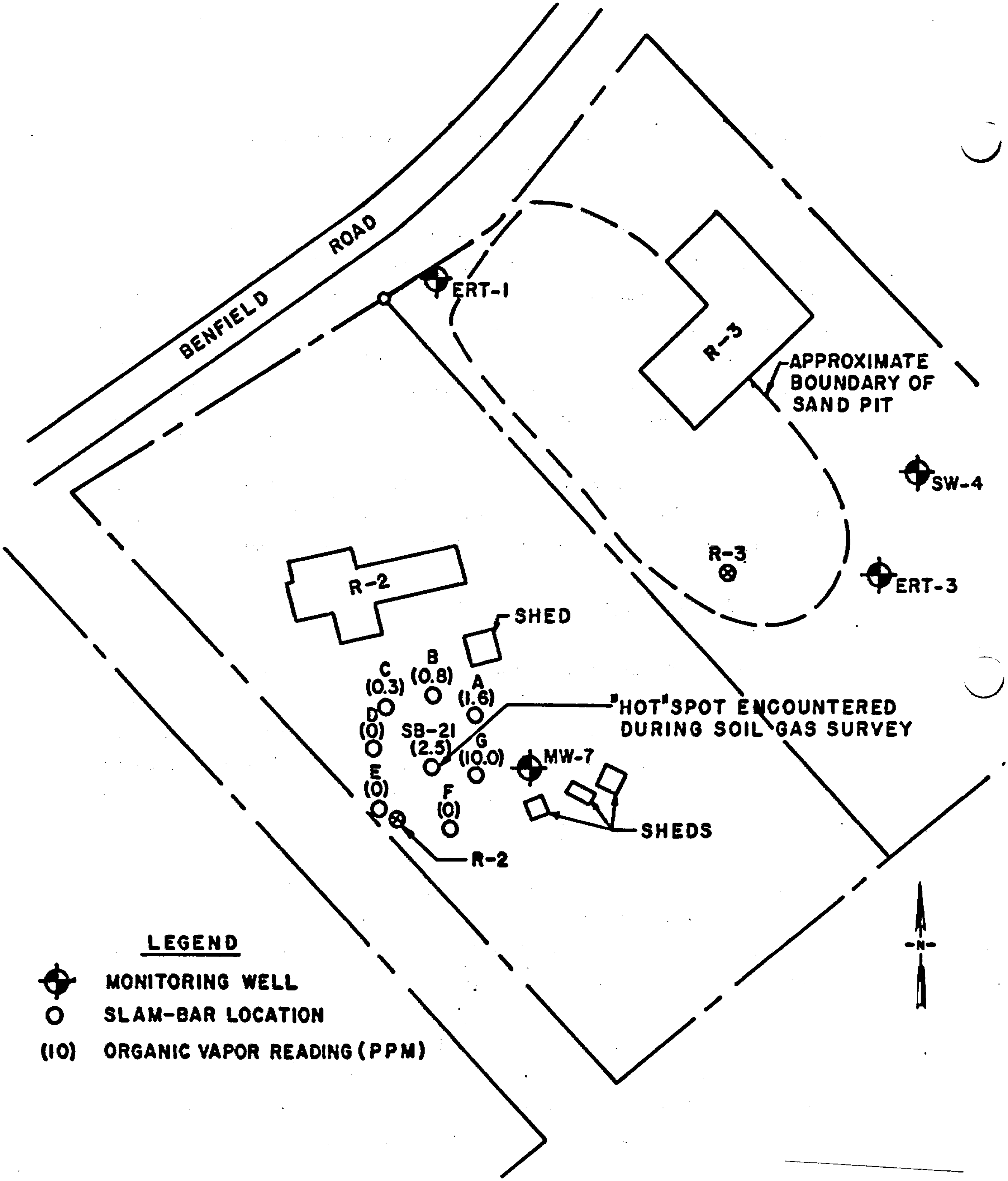


FIGURE 3-3
SOIL GAS READINGS ADJACENT TO SB-21
BERKS SAND PIT
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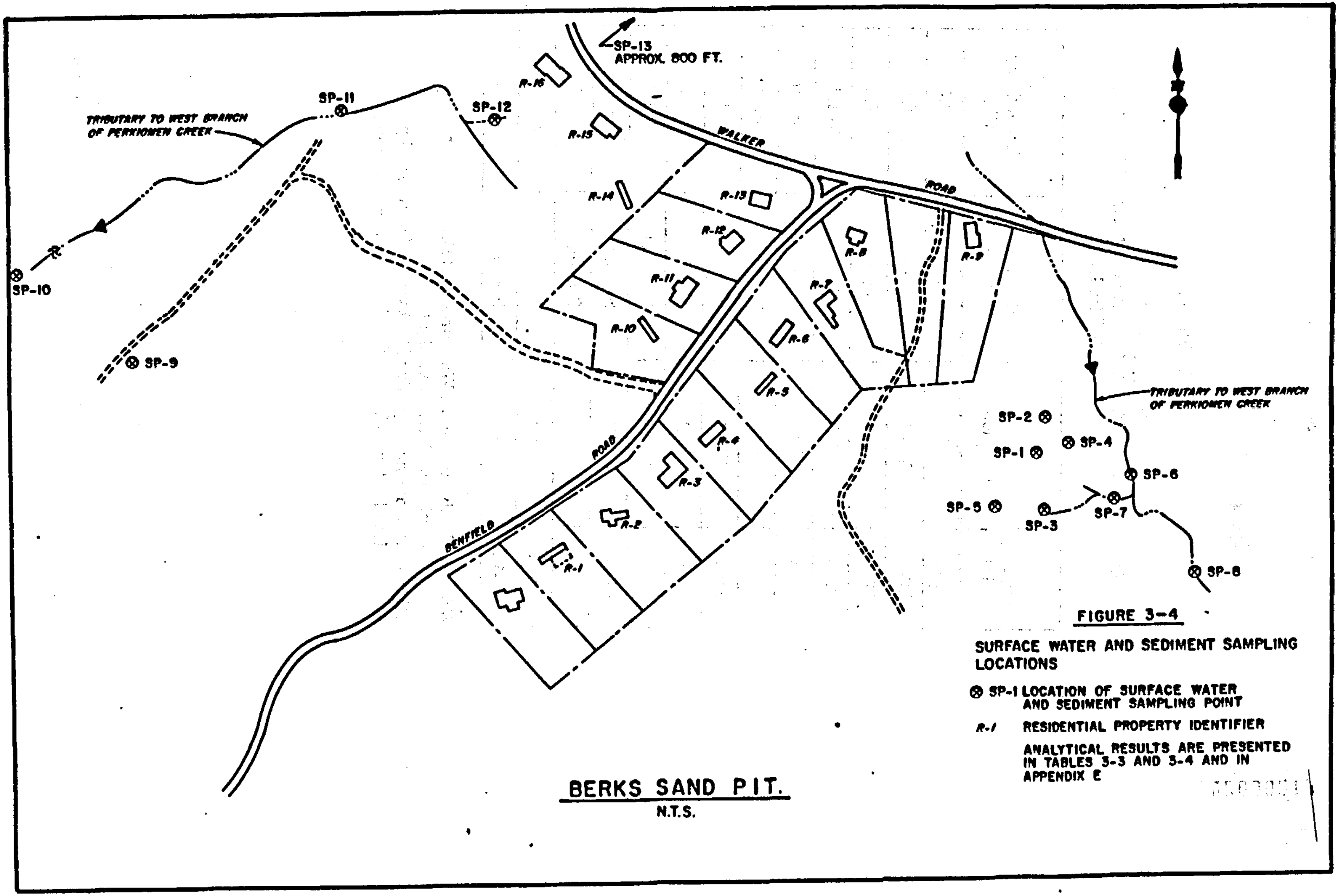

BERKS SAND P.I.T.
N.T.S.

FIGURE 3-4

SURFACE WATER AND SEDIMENT SAMPLING LOCATIONS

⊗ SP-1 LOCATION OF SURFACE WATER AND SEDIMENT SAMPLING POINT

R-1 RESIDENTIAL PROPERTY IDENTIFIER

ANALYTICAL RESULTS ARE PRESENTED IN TABLES 3-3 AND 3-4 AND IN APPENDIX E

Table 3-2

BERKS SAND PIT
SUMMARY OF SURFACE WATER AND SEDIMENT SAMPLING POINTS

Sampling Point	Location	Water Source Description	Depth of Sediment Sample (ft.)
SP-1	WBP	Seep	0 - 1.5
SP-2	WBP	Seep	Surface
SP-3	WBP	Spring	Surface
SP-4	WBP	Seep	0 - 1.5
SP-5	WBP	Seep	Surface
SP-6	WBP	Stream	Surface
SP-7	WBP	Stream	0 - 1.5
SP-8	WBP	Stream	0 - 1.5
SP-9	CGM	Mine Pool	0 - 1.5
SP-10	WBP	Stream	Surface
SP-11	WBP	Stream	0 - 1.5
SP-12	WBP	Spring	Surface
SP-13	S	Stream	0 - 1.5

WBP - Headwaters of the West Branch of Perkiomen Creek northeast of former sand pit.
CGM - Pool at ChaGery Mine Shaft west of former sand pit.
S - Headwaters of Swabia Creek north of former sand pit.

northwest of the former sand pit. These sampling points were included to account for possible secondary flow paths.

SP-13 is a stream sampling point in the headwaters of Swabia Creek north of the former sand pit. This sampling point was included to account for secondary flow paths and to note possible contamination from abandoned magnetite mines along Gap Road.

Two rounds of water samples and one round of sediment samples were taken at the 13 sampling points. The first sampling round was conducted in November 1987 and included both sediment and surface water sampling. Sediment samples for SP-1, SP-4, SP-7, SP-8, SP-9, SP-11, and SP-13 were taken with a standard split-spoon to a depth of 1.5 feet. Composite surface sediment samples for SP-2, SP-3, SP-5, SP-6, SP-10 and SP-12 were taken with disposable trowels because split-spoons could not be advanced due to frozen ground or the presence of rocks. The split-spoons were decontaminated with Alconox and water and rinsed with distilled/deionized water prior to sampling at each point. The trowels were rinsed with distilled/deionized water prior to use. Only one trowel was used per sample. Water samples were collected directly by imersing appropriate sample bottles in the surface water body.

All sediment samples were taken approximately 24 hours before the water samples. The reason for this was to prepare the sampling points for the water sampling, since in many cases, small holes had to be dug so that water could accumulate to a sufficient depth to be sampled. The sediments were allowed to settle for approximately 24 hours before the surface water samples were taken.

Only one sediment sample, SP-2 had detectable levels of volatile organics. SP-2 contained 240 µg/kg of 1,1-dichloroethane. Water samples for SP-13 were not collected because the stream was frozen. A detailed listing of the analytic results for the first surface water and sediment sampling round is provided in Appendix E. A summary of the surface water analytical results is given in Table 3-3.

The second sampling round was conducted in January and February, again in March 1988 and included only surface water sampling at the 13 sampling points. A detailed listing of the analytic results for the second round of surface water sampling is provided in Appendix E. A summary of these results is given in Table 3-4.

Table 3-3

BERKS SAND PIT
SUMMARY OF ANALYTICAL RESULTS FOR SURFACE WATER SAMPLES
TAKEN IN NOVEMBER 1987*

Sampling Point	1,1-dichloroethene (μg/l)	1,1-dichloroethane (μg/l)	1,1,1-trichloroethane (μg/l)	Tetrachloroethene (μg/l)
SP-1	**	**	**	ND
SP-2	**	**	**	ND
SP-3	19.00	**	64.00	ND
SP-4	38.00	**	120.00	ND
SP-5	ND	**	**	ND
SP-6	**	**	**	**
SP-7	17.00	**	62.00	ND
SP-8	**	**	**	**
SP-9	ND	ND	**	ND
SP-10	ND	ND	**	ND
SP-11	**	ND	ND	**
SP-12	ND	ND	ND	ND
SP-13	NS	NS	NS	NS

* Complete analytical results are given in Appendix E. This summary includes only indicator parameters resulting from the screening performed in Section 6.0.

ND = Not detected in sample
NS = No sample taken
** = did not pass QA/QC procedure

Table 3-4

BERKS SAND PIT
SUMMARY OF ANALYTICAL RESULTS FOR SURFACE WATER SAMPLES TAKEN IN MARCH 1988*

Sampling Point	1,1-dichloroethene (µg/l)	1,1-dichloroethane (µg/l)	1,1,1-trichloroethane (µg/l)	Tetrachloroethene (µg/l)
SP-1	990.00	ND	2,600.00	**
SP-2	84.00	ND	260.00	ND
SP-3	41.00	ND	330.00	ND
SP-4	66.00	ND	240.00	ND
SP-5	**	9.30	490.00	ND
SP-6	**	**	**	**
SP-7	**	**	**	**
SP-8	**	**	**	**
SP-9	**	ND	**	ND
SP-10	**	ND	ND	ND
SP-11	**	ND	**	ND
SP-12	ND	ND	ND	ND
SP-13	**	ND	ND	ND

* Complete analytical results are given in Appendix E. This summary includes only indicator parameters resulting from the screening performed in Section 6.0.

ND = Not detected in sample
** = did not pass QA/QC procedure

3.5 Drilling Program

An extensive drilling program was conducted in the vicinity of the former sand pit from August 1987 to November 1987. Pennsylvania Drilling Company was awarded the contract to perform the drilling, well installation, and packer tests at the Berks Sand Pit Site. The program included the completion of 19 soil borings, seven shallow monitoring wells (approximately 60 feet), and nine deep monitoring wells (approximately 150 feet), one of which was an exploratory well drilled to a depth of 300 feet. The location of the shallow and deep monitoring wells is shown in Figure 3-5 and Drawing 1.

3.5.1 Decontamination of Drilling Equipment

Each well drilled at the site required decontamination of the drill rigs, hand tools and downhole equipment prior to, and after, drilling and the packer tests. The decontamination included construction of a decontamination pit that was used to clean the drill rigs, equipment, and casing. The decontamination pit was constructed by grading a small area so that it was flat and slightly sloped in such a manner that the decontamination water could be collected and easily pumped into 55-gallon drums. The entire area was covered with plastic sheeting which was anchored in place by mounding soil around the edges. Sheets of plywood were placed in the pit so the plastic sheets would not be torn when the drill rigs were driven into and out of the pit.

The drilling rigs and all drilling tools were decontaminated by thoroughly steam cleaning with locally obtained potable water. If any areas did not appear visibly clean after steam cleaning, then that area was scrubbed with Alconox and water and rinsed with potable water.

All split-spoon samplers were decontaminated prior to each sample. All split-spoon soil samplers were scrubbed with Alconox and water and rinsed with potable water. Once the samplers appeared clean, a 5 percent nitric acid solution was applied. The nitric acid was thoroughly rinsed off with distilled-deionized water. The split-spoon samplers were then rinsed with methanol and air dried. Finally, the samplers were thoroughly rinsed with distilled deionized water and air dried.

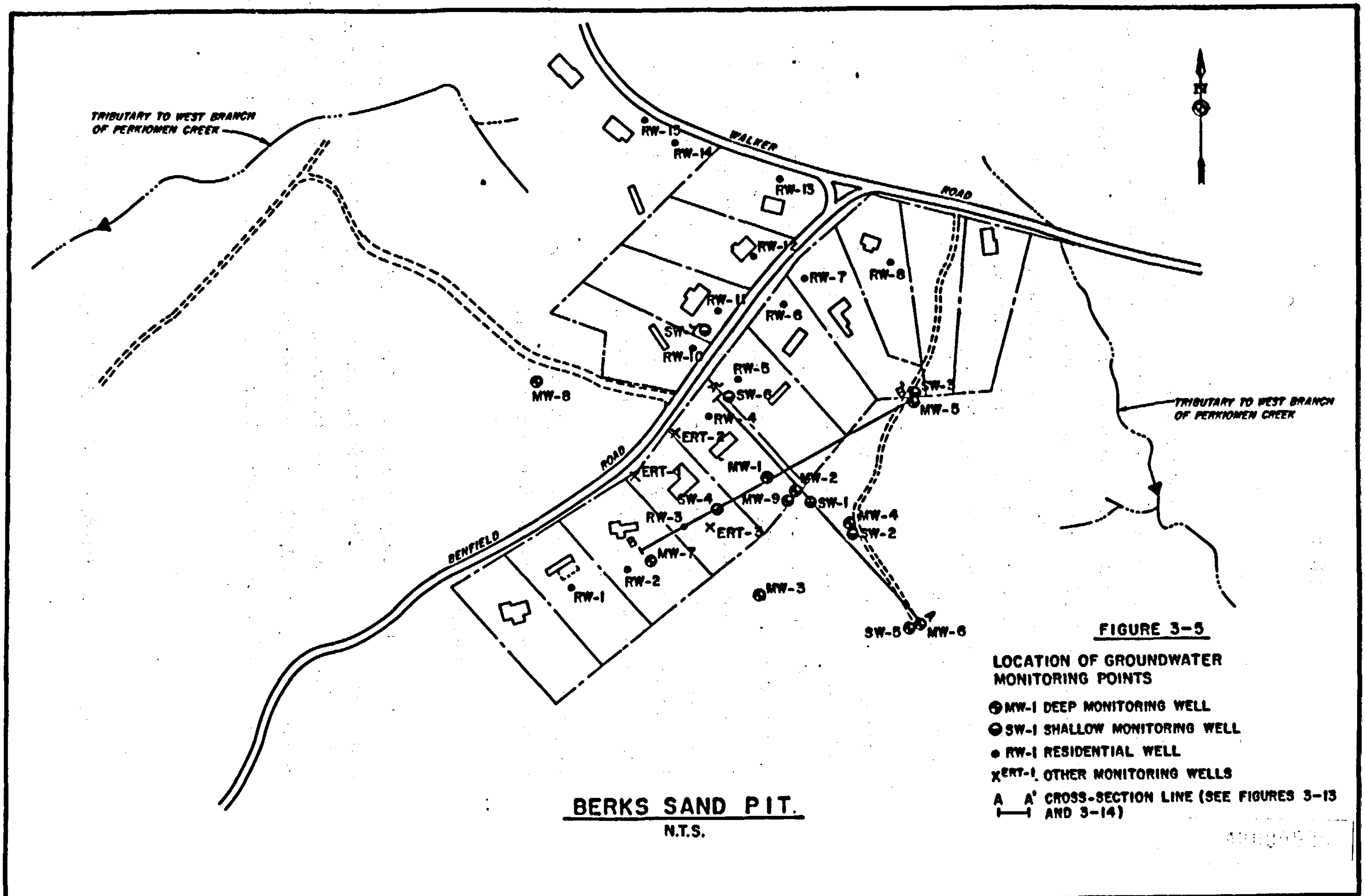

FIGURE 3-5

LOCATION OF GROUNDWATER MONITORING POINTS

3.5.2 On-Site Treatment System

A temporary on-site treatment system was constructed in September 1987 to store and treat contaminated groundwater pumped to the surface during the packer and pump tests, and from purging of the wells prior to sampling. The on-site treatment system consisted of three, 10,000 to 15,000 gallon storage pools and two portable, liquid phase activated carbon adsorption units (Cansorbs®). The entire treatment area was underlain by plastic sheeting held in place by mounded soil. A plastic lined trench was constructed down-slope from the treatment area to intercept runoff and spillage. A schematic diagram of the treatment system is shown in Figure 3-6.

Pumping discharge water was monitored with an OVA/PID. A headspace action level of 3 ppm was set by PADER/EPA. If the headspace OVA/PID readings were less than 3 ppm, the water was discharged to the watershed through aerators. If the headspace OVA/PID readings were greater than 3 ppm, the pumping discharge water was piped to the storage pools. The untreated water was pumped from the storage pools via a trash pump through filters and the Cansorbs® and into the treated water storage pool. Headspace readings were taken of the treated water to verify an adequate treatment level. The treated water was subsequently pumped from the storage pool, via trash pump, through aerators and to the watershed.

Decontamination water containing soaps, nitric acid, and/or hydraulic oils from the drilling rigs were containerized in 55-gallon drums rather than treated.

3.5.3 Soil Test Borings

Two sets of soil test borings were completed to determine the extent of near surface soil contamination in the vicinity of the former sand pit. The first set of soil borings, referred to with the TB designation, were completed between August 1987 and November 1987 in the former sand pit on the R-2, R-3, and R-4 properties. The second set of soil borings, referred to with the LTB designation were completed between August and September 1987 on the R-2

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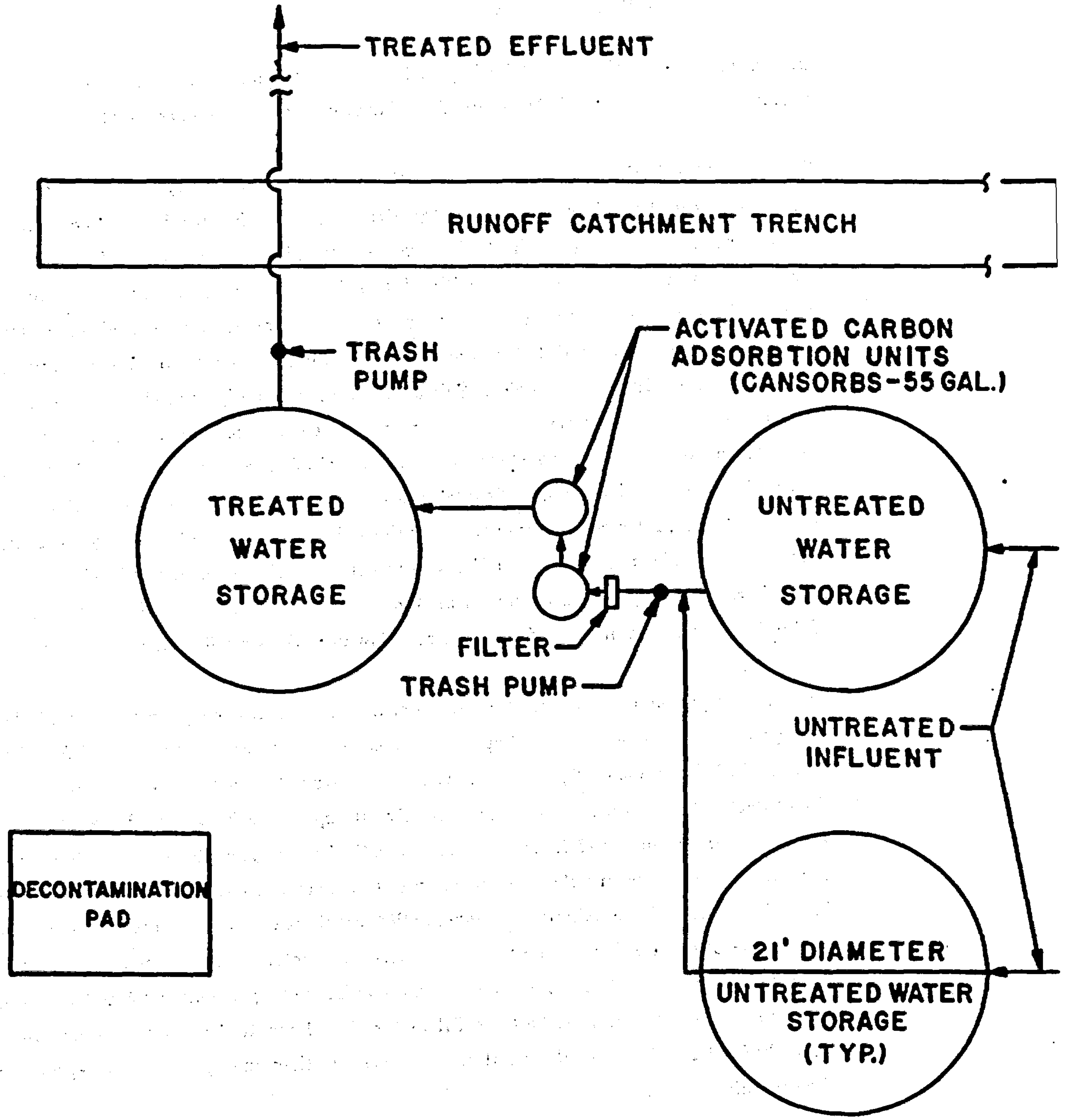

FIGURE 3-6
SCHEMATIC OF ON-SITE GROUNDWATER TREATMENT SYSTEM
BERKS SAND PIT
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property. An additional test boring, BG-1, was completed near the EPA Superfund (Longswamp Township Well Association) Well to provide a background control.

Twelve soil test borings with the TB designation were completed to depths of 9 feet to 20 feet in the vicinity of the former sand pit (see Drawing 1 and Figure 3-7 for locations and Appendix A for boring logs). The TB borings were completed with 6-inch O.D. hollow stem augers and split-spoon (2-foot length with 2-inch I.D.). Continuous split-spoon samples were taken where possible, however, the presence of boulders at some sampling locations prohibited this activity in all holes. Downhole, breathing zone, and soil OVA readings were taken between split-spoon samples. Soil samples were visually logged and screened for volatile organics with an OVA. Two criterion were used to select samples for laboratory analysis as outlined in the Operations Plan: OVA readings and visible signs of contamination. No visible signs of contamination were noted in the soils at the Berks Sand Pit Site. Hence, selected soil samples were collected and sent to the laboratory for analysis from those samples that displayed OVA readings elevated above background. The results of the laboratory analyses are presented in Appendix E and discussed later in this section. Table 3-5 provides a summary of the maximum downhole OVA readings for the TB borings.

OVA readings taken in the field from three of the 12 TB soil borings were elevated above background (see Table 3-5). Split-spoon samples from TB-6 for the 9-foot to 13-foot depth exhibited OVA readings of 6 ppm to 8 ppm above background. Downhole OVA readings at the 9-foot depth showed readings of approximately 100 ppm. TB-7 exhibited elevated OVA readings at the 10-foot to 15-foot depth. Downhole OVA readings of 200 ppm to 300 ppm were recorded with split-spoon soil sample readings of 15 ppm to 20 ppm and less than 1 ppm in the breathing zone. TB-10 exhibited downhole OVA readings of 5 ppm at the 2-foot to 4-foot depth. Six of the TB borings on the R-3 property encountered fill to depths ranging from 4 feet to 10 feet. It should be noted that maximum OVA readings in both TB-6 and TB-7 were encountered near the contact between fill material and residual soils and/or weathered bedrock; OVA readings for all TB soil borings were less than one ppm above background in the breathing zone.

Test borings TB-1, TB-2, TB-3, TB-10, and TB-11 all encountered highly weathered granitic gneiss throughout the depth of the boring. TB-4, TB-5, TB-6, TB-7, TB-8, and TB-9 all encountered loose sandy fill near the surface (note that TB-8 and TB-9 are located on the R-4 property). The fill is underlain by either saprolite (TB-5, TB-8, and TB-9) or highly weathere

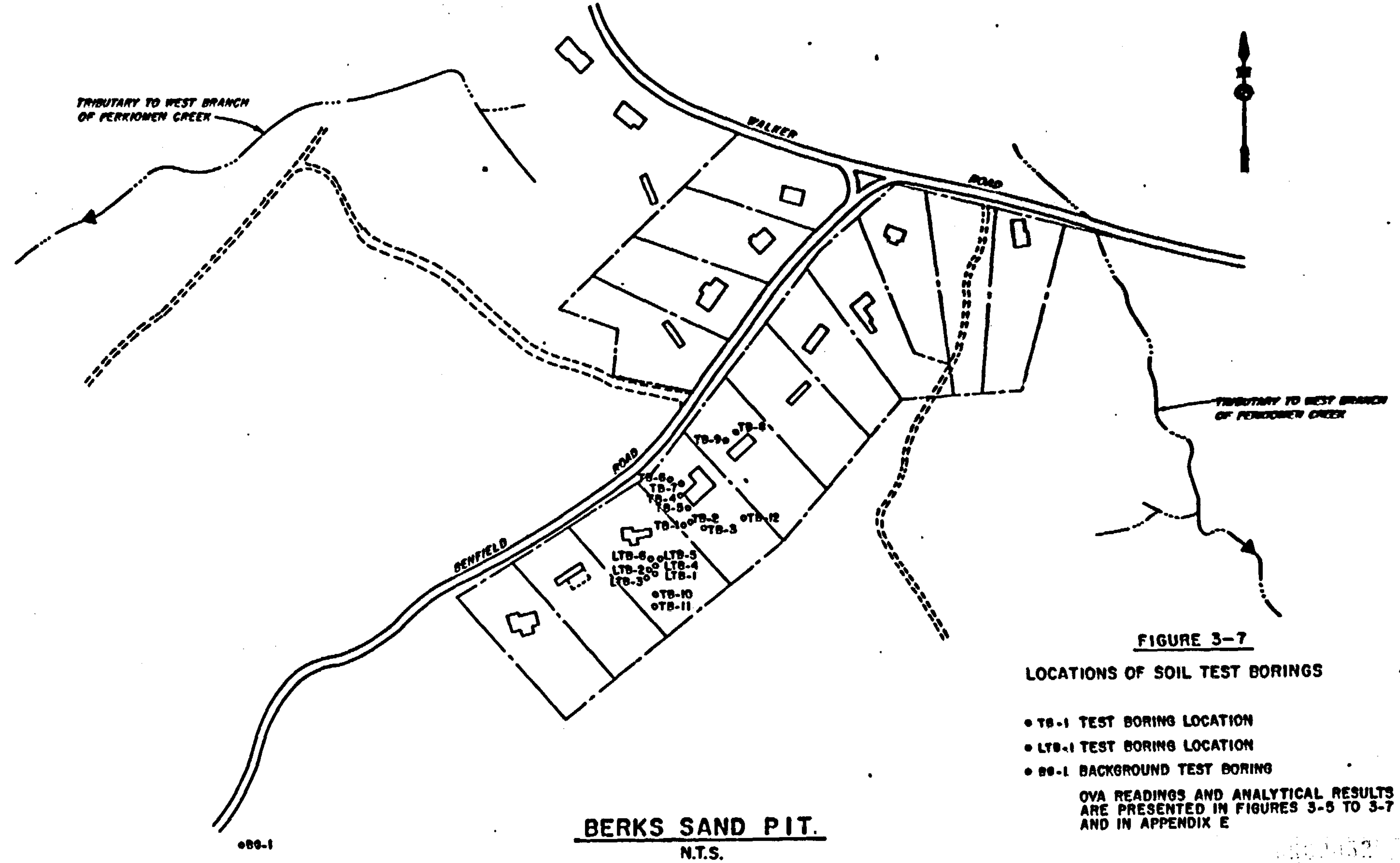


FIGURE 3-7

LOCATIONS OF SOIL TEST BORINGS

- TB-1 TEST BORING LOCATION
- LTB-1 TEST BORING LOCATION
- BG-1 BACKGROUND TEST BORING

OVA READINGS AND ANALYTICAL RESULTS ARE PRESENTED IN FIGURES 3-5 TO 3-7 AND IN APPENDIX E

BERKS SAND PIT.
N.T.S.

Table 3-5

BERKS SAND PIT
SUMMARY OF MAXIMUM DOWNHOLE OVA READINGS (ppm)
FOR TB SOIL TEST BORINGS

Depth (ft)	TB-6	TB-7	TB-10
2 to 4	-	-	5
8 to 10	100	-	-
10 to 12	8	200 to 300	-
12 to 14	8	-	-

granitic gneiss (TB-4, TB-6, and TB-7). The fill material was encountered to a maximum depth of 10 feet in TB-4 and TB-6. No boring log was produced for TB-12.

A total of 19 soil samples were selected for analysis from the TB soil borings based on OVA and visual screening. Selected soil samples that exhibited OVA readings elevated above background were submitted for laboratory analysis. No visual evidence of contamination was observed. No soil samples were collected for TB-1. None of the five indicator parameters, as described in Section 6.0 were detected in the soil samples. Complete analytical results are presented in Appendix E.

Six soil borings with the LTB designation were completed to depths of approximately 4 feet to 11 feet on the R-2 property. These borings were located in the vicinity of SB21 to investigate the area of elevated organic soil gas as determined from the slam-bar soil gas survey. The LTB soil borings were initiated with a hand-operated power auger. Auger cuttings were screened with an OVA and samples exhibiting elevated readings were composited for laboratory analysis. Borings exhibiting elevated OVA readings were further advanced with an Acker Drill Rig using 6-inch O.D. hollow stem augers and standard split-spoons. Downhole and breathing zone OVA readings were recorded after each split-spoon sample. A summary of downhole OVA readings is given in Table 3-6.

Five of the six LTB soil borings exhibited elevated OVA readings. LTB-1 showed a maximum downhole reading of 20 ppm above background for the 0-foot to 2-foot depth; LTB-2 showed a maximum downhole reading of 1.4 ppm above background for the 0-foot to 2-foot depth; LTB-3 showed no readings above background; LTB-5 showed a consistent downhole reading of 3 ppm background for the 0-foot to 3-foot depth; LTB-6 showed a maximum downhole reading of 5 ppm above background for the 4-foot to 6-foot depth.

LTB-4 showed the most significant downhole OVA readings and was completed with Level C personal protection. A maximum downhole reading of 200 ppm to 300 ppm above background was encountered at the 3-foot to 5-foot depth. After letting the hole vent for approximately 15 minutes, the downhole OVA readings dropped to approximately 50 ppm above background. The downhole OVA readings dropped to less than 1 ppm above background below 8 feet.

All of the LTB soil borings encountered sand and clay near the surface underlain by either saprolite or highly-weathered granitic gneiss. A total of 10 soil samples were collected at the LTB locations: Five samples are composites of the hand (power) auger cuttings and five

Table 3-6

SUMMARY OF MAXIMUM DOWNHOLE OVA READINGS (ppm) FOR LTB SOIL BORINGS*

Depth (ft.)	LTB-1	LTB-2	LTB-3	LTB-4	LTB-5	LTB-6
0 - 1	20	1.4	-	60	3	-
1 - 2	20	1.4	-	60	3	-
2 - 3	1.5	0.8	-	60	3	-
3 - 4	2.1	0.8	-	200 - 300	- ///	-
4 - 5	2.1	-	///	200 - 300		5
5 - 6	-	-		30		5
6 - 7	-	-		30		-
7 - 8	-	-		3		-
8 - 9	-	-		<1 ///		-
9 - 10	///	-				- ///
10 - 11		- ///				

— OVA reading not above background.

/// Bottom of soil boring.

*All readings are reported as above background.

samples were collected with standard split-spoons. No volatile or semi-volatile organics were detected in any of the 10 soil samples submitted for laboratory analysis. Complete analytical results are presented in Appendix E.

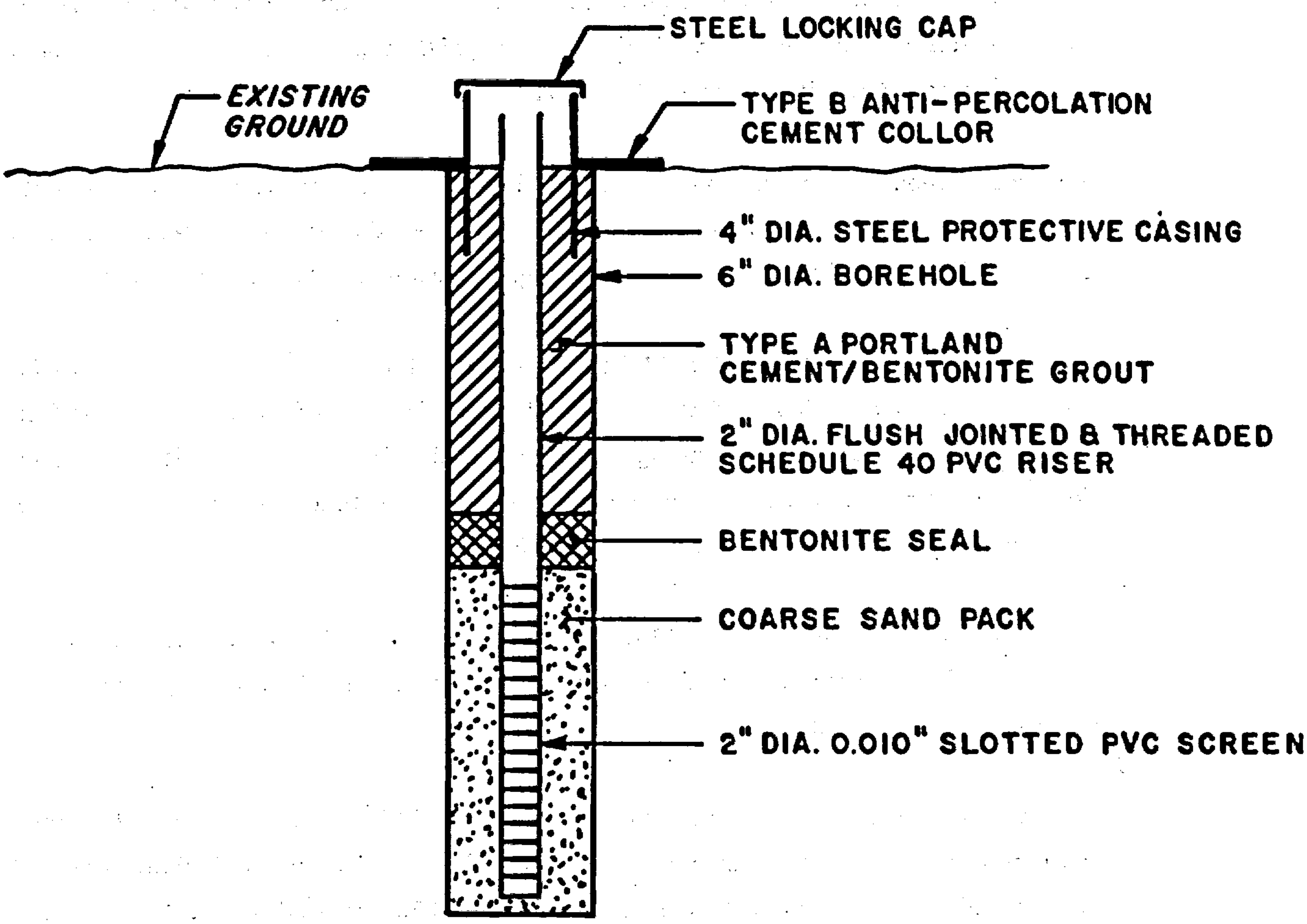
3.5.4 Shallow Monitoring Wells

Seven shallow monitoring wells (SW) were installed in areas downgradient from the former sand pit as part of the drilling program. The purpose of the shallow wells was to characterize the soil and water in the weathered zone above competent bedrock, to identify a possible ground water flow regime in the soil and to enable this regime to be monitored if present. These seven wells were not part of the original work plan. They were added after the start of the drilling program in October 1987 as an amendment to the original engineering agreement to facilitate the investigation of the shallow, weathered zone aquifer.

The seven SW wells were installed to depths of 40 to 60 feet with a combination of hollow stem augering and air hammer/rotary techniques. The wells were cased with 2-inch diameter schedule 40 PVC flush jointed and threaded casing with 30 feet to 40 feet of 0.020-inch slotted PVC screen. Silica sand was placed in the annulus adjacent to and at least 1 foot above the screened interval. A bentonite pellet seal was placed immediately above the sand pack and the remainder of the annulus was grouted with portland cement mixed with bentonite powder at a 4 percent ratio. A generalized well construction diagram for the SW monitoring wells is given in Figure 3-8. Additional well construction details are provided in the logs contained in Appendix A.

SW-1 was drilled to a total depth of 63 feet. Clay and weathered granitic gneiss were encountered to a depth of 16 feet and saprolite and highly weathered granitic gneiss from 16 feet to 40 feet. No cuttings were returned from 40 feet to 47 feet. Competent bedrock (granitic gneiss) was encountered at approximately 60 feet.

SW-2 was drilled to a total of 61 feet. Saprolite and highly weathered granitic gneiss were observed to a depth of 41 feet. Competent bedrock was present from 41 feet to 61 feet, though there were numerous "soft zones" throughout this interval. Water was encountered at 31 feet with a production rate of approximately 3 gpm to 5 gpm. Water production increased to about 50 gpm at the 50-foot depth.



NOTE: SPECIFIC WELL CONSTRUCTION DETAILS FOR THE SHALLOW (SW) MONITORING WELLS ARE GIVEN IN APPENDIX A

FIGURE 3-8
BERKS SAND PIT
GENERALIZED WELL CONSTRUCTION DETAILS
FOR SW MONITORING WELLS

SW-3 was drilled to a total depth of 50 feet. A clay zone was noted from the surface to 9 feet and weathered granitic gneiss from 9 feet to 17 feet. A very wet and sandy saprolite zone was encountered from 17 feet to 45 feet. Significant caving of the saprolite occurred from 32 feet to 45 feet. Competent granitic gneiss was hit at 45 feet.

SW-4 was drilled to a total depth of 62 feet. Highly weathered granitic gneiss and saprolite were noted to a depth of approximately 13 feet. Fresh, unweathered bedrock was encountered at 13 feet. Water was first noticed at 36 feet though production was low (5 gpm to 10 gpm).

SW-5 was drilled to a total depth of 61 feet. Saprolite and highly weathered granitic gneiss were observed to a depth of 16 feet; hard granitic gneiss was noted from 16 feet to 61 feet. There were numerous soft zones throughout this interval. Water was first noticed at 23 feet. Water production increased to about 25 gpm at 44 feet indicating a possible fracture zone. Water production dropped to about 20 gpm below 51 feet.

SW-6 was drilled to a total depth of 61 feet. Saprolite was present to 8 feet where competent granitic gneiss was encountered. Water was first noticed at about 21 feet though production was low (1 gpm to 2 gpm).

SW-7 was drilled to a total depth of 44 feet. Saprolite and highly weathered granitic gneiss were present to a depth of 40 feet where competent bedrock was encountered. Water was first noticed at about 20 feet and thick mud was encountered at 33 feet. Drilling was terminated at 44 feet because of running and heaving sands and caving of the hole.

In general, the SW borings indicate a saprolitic zone of varying thickness underlain by competent bedrock. The depth to bedrock ranged from 8 feet in SW-6 to 60 feet in SW-1. Water was encountered in both the saprolite and in the bedrock. Increased water production during drilling was usually in association with "soft" or fractured zones. Boring logs and well construction details are provided in Appendix A.

3.5.5 Deep Monitoring Wells

Nine deep monitoring wells (MW) were, in general, installed in potential downgradient areas from the former sand pit as part of the drilling program. The purpose of the deep wells was to characterize the fractured bedrock aquifer by: 1)identifying the subsurface lithologies, 2) identifying the nature and extent of the fractures; 3) sampling the subsurface soils, rocks and water; and 4) enabling a deep, fractured bedrock flow regime to be monitored. The deep monitoring wells, through the use of packer and pump tests (see Section 3.6), also were used to aid in delineating a vertical profile of contamination and the hydrogeologic properties of the bedrock.

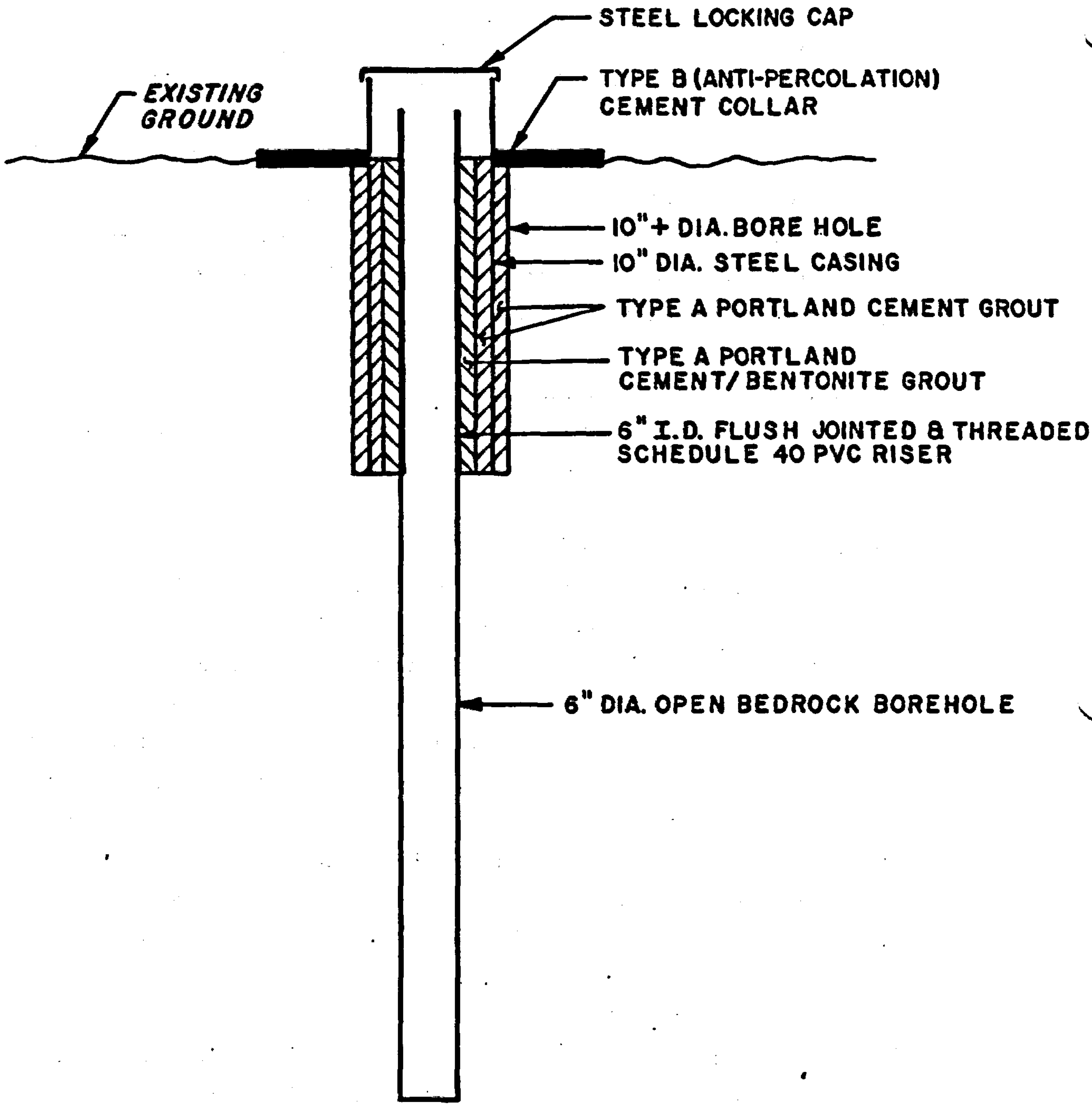
Eight monitoring wells (MW-1 and MW-3 through MW-8) were installed to a depth of approximately 150 feet and one exploratory monitoring well (MW-2) was installed to a depth of approximately 300 feet. Boring logs and well construction details are given in Appendix A. A generalized well construction detail is given in Figure 3-9.

Initial drilling activities consisted of a soil sampling program in the overburden. Soil borings were advanced with a truck-mounted drilling rig using six-inch O.D. hollow stem augers. The borings were advanced to auger refusal.

Continuous soil samples were collected with a three-inch O.D., 24-inch long split-spoon sampler. Split-spoon sampling and standard penetration tests were performed in accordance with ASTM Method D1586. Soil samples were visually logged and were screened with an OVA. Samples which indicated OVA readings greater than background were submitted for laboratory analysis. Soil samples were removed from the split-spoon with a disposable wooden spatula. For those samples that were submitted for laboratory analysis, a portion of the soil was packed into two 40-ml zero-head space glass vials and sealed tightly with teflon-lined lids for volatile organic analyses. The remaining portion of the samples were placed in 950-ml glass containers and sealed tightly with a teflon lid for semi-volatile organic and inorganic analyses. No chemical preservatives were added to the soil samples. All samples were properly labeled and documented, and each sample was placed in a cooler and cooled to 4°C with ice. Complete analytical results are given in Appendix E

After the soil sampling was completed, the hole was reamed and a 10-inch steel casing was installed to the top of rock. The casing was set in place and the annular space around, and within the steel casing was grouted with cement. After allowing the cement grout to set-up, an eight-inch diameter hole was advanced through the grout with an air hammer/rotary rig to a depth of 30 feet to 60 feet.

A six-inch I.D. schedule 40, flush jointed and threaded PVC casing was then installed into the excavated borehole. The annular space around the PVC casing was tremie grouted to the surface with a cement grout mixed with 4 percent bentonite.



NOTE: SPECIFIC WELL CONSTRUCTION DETAILS FOR THE DEEP (MW) MONITORING WELLS ARE GIVEN IN APPENDIX A

FIGURE 3-9
BERKS SAND PIT
GENERALIZED WELL CONSTRUCTION DETAILS
FOR MW MONITORING WELLS

After allowing the cement-bentonite grout to set, a six-inch I.D. borehole was advanced with an air hammer/rotary rig from the base of the PVC casing to a depth of approximately 150 feet. Monitoring wells MW-1, MW-2, MW-3, MW-5, MW-6, MW-7, and MW-8 were completed in this manner.

Monitoring wells MW-4 and MW-9 were continuously cored to a depth of 150 feet from the base of the PVC casing. These wells were cored with NX sized drilling equipment which yields a 1.98-inch diameter core and a 2.98-inch diameter borehole. MW-2 was continuously cored with NX equipment from approximately 150 feet to 300 feet. The cores were visually logged for lithologic changes and fracture/joint dip angles and rock quality were measured. Core orientation was not measured. The cores were wrapped in plastic and placed in wooden core boxes for storage.

All monitoring wells, except MW-4, were completed as open bedrock wells of six-inch diameter below the PVC casing. Monitoring well MW-4 was highly fractured; consequently it was cased with a nominal four-inch diameter, schedule 40, flush jointed and threaded PVC casing to a depth of 60 feet. The well was terminated with 90 feet of 4-inch diameter, 0.010-inch slotted PVC screen. The annular space between the screen and the borehole wall was backfilled with silica sand to the base of the six-inch diameter casing.

Type B anti-percolation concrete collars and steel locking caps were installed at each well. The monitoring wells were developed by surging with compressed air for at least one-half hour or until the development water was clear and sediment free. Auger cuttings, air hammer/rotary drilling development soil and/or rock ships which displayed signs of contamination (visual or with OVA screening) were containerized for off-site disposal.

Following is a brief narrative description of each of the monitoring wells:

- MW-1 was drilled to a total depth of 152 feet. Alternating layers of clay, sand and saprolite were encountered to a depth of 16.5 feet; highly weathered granitic gneiss from 16.5 feet to 80 feet; and fresh granitic gneiss from approximately 80 feet to 152 feet of water was first observed at a depth of approximately 43 feet below the ground surface.

The granitic gneiss encountered in this boring contained quartz, feldspar, hornblende and biotite. Local zones (115 feet to 129 feet) were chlorite rich and well foliated. There was some evidence of hematitic staining on the drill cuttings from approximately 146 feet. Two possible major fracture zones were noted during drilling at 48 feet and from 107 feet to 112 feet. The fracture zone from 107 feet to 112 feet was associated with an increased groundwater discharge rate from about 8 gpm to 20 gpm to 30 gpm.

- MW-2 was drilled to a total depth of 300 feet. Clayey sand was encountered to a depth of 8.5 feet; alternating layers of saprolite and highly weathered granitic gneiss from 8.5 feet to 15 feet; highly weathered granitic gneiss from 15 feet to 60 feet; and fresh granitic gneiss from 60 feet to 300 feet. Water was encountered at a depth of approximately 41 feet below the ground surface.

  The granitic gneiss encountered in this boring contained quartz with some feldspar, hornblende, and biotite. Alternating layers of green to black, well foliated chlorite-rich granitic gneiss and orange to white quartz and feldspar-rich permatites were encountered throughout the borehole. Many fracture zones were noted in the cores and hematite and chlorite staining was observed on some fracture surfaces. Slickensides also were noted on some fracture surfaces. Predominant fracture dip angles, as measured from the NX cored are 30° to 35°, 40° to 45°, and 50° to 55°. Detailed boring logs and fracture dip angle measurements are given in Appendix A.

- MW-3 was drilled to a total depth of 155 feet. Saprolite was encountered to a depth of 3.5 feet; highly weathered granitic gneiss from 3.5 feet to 13 feet, and fresh granitic gneiss from 13 feet to 155 feet.

  Fracture zones were noted from depths of 32 feet to 35 feet, 38.5 feet to 39.5 feet, and 40 feet to 41 feet. Few drill cuttings were returned below a depth of 47 feet indicating a possible major fracture zone. Numerous soft zones were encountered throughout the depth of the borehole; there was no resistance to drilling from 81 feet to 82.5 feet.

- MW-4 was drilled to a total depth of 150 feet. Saprolite was encountered to a depth of 31.5 feet; highly weathered granitic gneiss from 31.5 feet to 72 feet; and fresh granitic gneiss from 72 feet to 150 feet. Water was first observed in the saprolite at a depth of approximately 17.5 feet below the ground surface.

The granitic gneiss encountered in this boring contained quartz and feldspar with some hornblende and chlorite. Some micaeous and chlorite-rich zones also were noted. In general, the most highly fractured zones contained micaeous and chlorite-rich seams. Chlorite and hematitic staining, and slickensides were noted on some fracture surfaces. Predominant fracture dip angles, as measured from the NX cores are 40° to 45°, and 70° to 75°.

- MW-5 was drilled to a total depth of 153 feet. Silty clay and clayey sand were encountered to a depth of 9 feet; highly weathered granitic gneiss and saprolite from 9 feet to 28 feet; weathered to highly weathered granitic gneiss from 28 feet to 105 feet; and fresh granitic gneiss from 105 feet to 153 feet. Water was first observed approximately 47 feet below the ground surface.

  Potential fracture zones were noted at depths of 96 feet and 116 feet to 118 feet. The return water discharge rate increased progressively with depth from about 5 gpm at 93 feet to about 40 gpm at 150 feet. Since water was not used during drilling (air hammer), discharge from the borehole represented formation water.

- MW-6 was drilled to a total depth of 150 feet. Clayey sand was encountered to a depth of 2.5 feet; saprolite from 2.5 feet to about 31 feet; highly weathered granitic gneiss from 31 feet to 80 feet; and fresh granitic gneiss from 80 feet to 150 feet. Massive magnetite was present from 89 to 92 feet and quartz with diseminated magnetite from 92 feet to 99 feet. Water was first encountered in the saprolite at a depth of 20 feet below the ground surface.

  Borehole collapse and caving of highly weathered granitic gneiss between 35 feet and 66 feet slowed drilling activities. This zone is highly weathered and possibly represents a major fracture zone. The discharge rate increased from about 2 gpm at 60 feet to 30 gpm at 66 feet. A further increase in discharge rate, from 30 gpm to 50 gpm, occurred at about 140 feet.

- MW-7 was drilled to a total depth of 153 feet. Clayey sand was encountered to a depth of 5.5 feet; highly weathered granitic gneiss from 5.5 feet to 57 feet; and fresh granitic gneiss from 51 feet to 153 feet. A magnetite-rich pegmatite was encountered at a depth of 108 feet to 115 feet. Water was first observed at 22 feet below the ground surface.

Four fracture zones were noted during drilling: at 80 feet, 107 feet, 108 to 110 feet, and 138 feet. The discharge rate during drilling was quite low (3 gpm to 8 gpm) throughout the depth of the borehole.

- MW-8 was drilled to a total depth of 150 feet. Clayey sand was encountered to a depth of about 4 feet; saprolite from 4 feet to 10.5 feet; highly weathered granitic gneiss from 10.5 feet to 24 feet; and fresh granitic gneiss from 44 feet to 150 feet. Highly weathered magnetite was noted at 24 feet to 32 feet and less weathered, massive magnetite from 32 feet to 44 feet. Water was first observed at 42 feet below the ground surface in the massive magnetite.

  No major fracture zones were noted during the drilling of MW-8. The discharge rate increased steadily with depth from about 5 gpm at 54 feet to 15 gpm at 93 feet.

- MW-9 was drilled to a total depth of 151 feet. Saprolite was encountered to a depth of 9.5 feet; highly weathered granitic gneiss from 9.5 feet to 54 feet; and fresh granitic gneiss from 54 feet to 151 feet.

  In general, the granitic gneiss consists of quartz and feldspar with some hornblende and chlorite. Occasional quartz or chlorite veins were noted. A micaceous (biotite) zone was observed from 72.5 feet to 73.2 feet. Quartz and feldspar rich granitic gneiss alternating with quartz and biotite-rich granitic gneiss was observed from 130 feet to 151 feet.

  Numerous fracture zones occur throughout the depth of the borehole; 100 feet of drilling tools were lost in the original hole after collapse of the borehole. A second borehole was completed a few feet from the first.

  Fracture dip angles, as measured from the NX cores are predominately 40° to 50° and 65° to 75°.

3.6 Aquifer Testing

Two types of aquifer tests were performed at the Berks Sand Pit Site to estimate the hydrogeologic properties of the bedrock. Packer tests were performed on six deep monitoring wells (MW) to obtain transmissivity estimates and to develop concentration versus depth relationships. Three successful pump tests also were performed to estimate the transmissivity of the bedrock aquifer.

3.6.1 Packer Tests

Straddle packer pump tests were performed in six of the nine MW wells at selected 10-foot intervals. The purpose of the packer pump tests were two-fold:

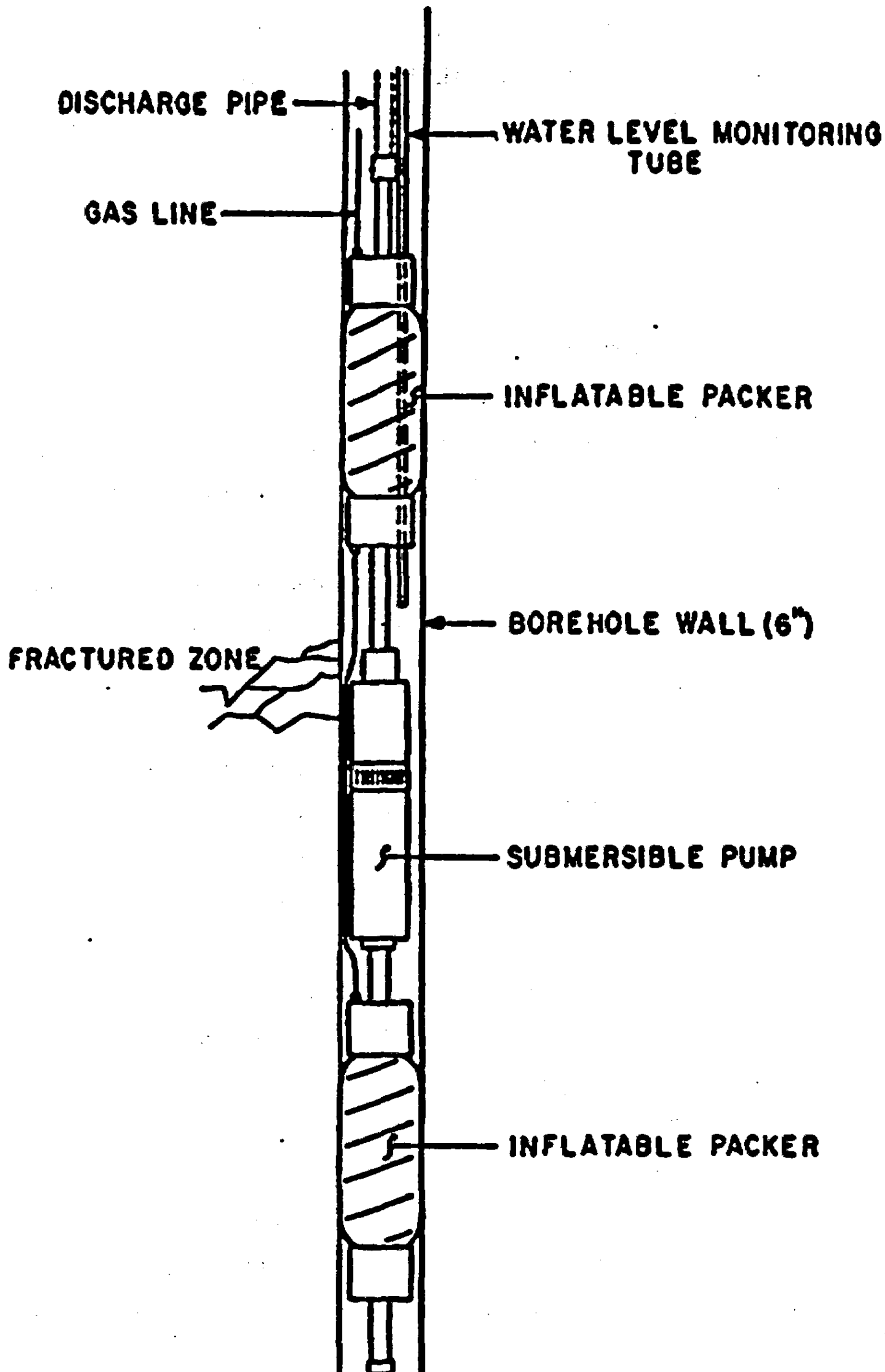
- To obtain transmissivity (T) estimates in potential fracture zones, and
- To estimate concentration versus depth relationships from sampling selected fracture zones.

All test intervals were selected to correspond with potential zones of fractured bedrock as interpreted from the downhole geophysical logs and the borehole drilling logs. The geophysical investigation is discussed in Section 3.7.

The typical straddle packer assembly, as illustrated in Figure 3-10, consisted of two inflatable packers positioned 10 feet apart. A submersible pump was placed between the packers with the pump intake approximately 5 feet above the top of the bottom packer. Water levels in the packed-off interval were measured in a PVC standpipe connected to a steel tube penetrating the upper packer.

To avoid cross contamination between the monitoring wells, all packer equipment was steam cleaned prior to use in each well. Also, to avoid possible contamination of natural groundwater, water was pumped out of the test interval rather than injected into the interval.

After the packer assembly was set at the selected test interval, the static water level within the test zone was allowed to equilibrate. Each test interval was pumped for a nominal 45 minutes, though many of the test intervals were devoid of water so that pumping was not



TYPICAL STRADDLE PACKER—PUMPING SYSTEM

possible. The discharge water was monitored with an OVA and pumped to the treatment area for storage and later treatment.

A total of 23 packer tests were performed in monitoring wells MW-1, MW-2, MW-3, MW-5, MW-6, and MW-7. Of the 23 tests, 15 yielded sufficient data for transmissivity calculations and 19 water samples were collected for laboratory analysis (see Table 3-7 for a summary of the packer tests). Time drawdown data collected during the packer tests was evaluated with the Copper and Jacob straight-line time-drawdown method. The Jacobs straight-line method was used to yield a transmissivity estimate for the bedrock near the well in the test interval. This method of analysis is applicable to the packer tests performed in the boreholes because water levels in the test inteval were measured via a standpipe that penetrated the upper packer. However, since the pumping duration was relatively short (45 minutes maximum) the zone of influence beyond the borehole was small. Hence, the transmissivities calculated from the time-drawdown data are only estimates of the transmissivities in a particular 10-foot interval, near the borehole. A description of the Jacobs straight-line method is given in Appendix C.

The calculated transmissivity values are only order of magnitude estimates because:

1. The assumptions inherent in the Jacobs straight line method were not necessarily completely satisfied; however, this method generally yields reliable, order of magnitude estimates for a broad range of hydrogeologic conditions.

2. The packers may not have effectively isolated the test zone and leakage from adjacent zones may have occurred.

3. There were small variations in the pumping rates which could affect the transmissivity calculations. However, for drawdown data that was used to calculate transmissivities, the pumping rates generally displayed less than 10 percent variability.

4. The duration of pumping from each interval was short. Therefore, the estimated transmissivities are representative of only a particular 10-foot test interval near the borehole.

5. Steady state flow conditions were not achieved during the packer tests.

Table 3-7

BERKS SAND PIT
SUMMARY OF PACKER TESTS

MW-1

Elevation of Test Interval (ft MSL)	Pump Rate Q (gpm)	Transmissivity T (gpd/ft)	Sample Depth (ft)	Comments
908.66 - 898.66	23	830	75 - 85	Duration = 45 minutes
874.66 - 864.66	23.5	2,100	109 - 119	Duration = 45 minutes

MW-2

Elevation of Test Interval (ft MSL)	Pump Rate Q (gpm)	Transmissivity T (gpd/ft)	Sample Depth (ft)	Comments
909.53 - 899.53	~16	180	70 - 80	Variable pumping rate
899.53 - 889.53	21	1,980	80 - 90	Duration = 45 minutes
884.53 - 874.53	22	480 750	95 - 105	Duration = 45 minutes
859.43 - 849.43	~0	-	120 - 130	Little water
829.53 - 819.53	0	-	-	No water
806.53 - 796.53	0	-	-	No water
779.53 - 769.53	0	-	-	No water
759.53 - 717.53	~0	-	-	Pumped 2.3 minutes
727.53 - 717.53	~15	1,220	252 - 262	Variable response (drawdown) with time

Table 3-7

BERKS SAND PIT
SUMMARY OF PACKER TESTS
-continued-

MW-3

Elevation of Test Interval (ft MSL)	Pump Rate Q (gpm)	Transmissivity T (gpd/ft)	Sample Depth (ft)	Comments
920.33 - 910.33	13	26,400 10,100	75 - 85	Duration = 45 minutes
900.33 - 890.33	10	26,400	95 - 105	Duration = 45 minutes
880.33 - 870.33	1 - 2	-	115 - 125	Slow, variable pumping rate

MW-5

Elevation of Test Interval (ft MSL)	Pump Rate Q (gpm)	Transmissivity T (gpd/ft)	Sample Depth (ft)	Comments
905.19 - 895.19	~23	6,750 4,670	68 - 78	Duration = 45 minutes
883.19 - 873.19	9	2,800	90 - 100	Duration = 45 minutes
853.19 - 843.19	~0	-	120 - 130	Little water

Table 3-7

BERKS SAND PIT
SUMMARY OF PACKER TESTS
-continued-

MW-6

Elevation of Test Interval (ft MSL)	Pump Rate Q (gpm)	Transmissivity T (gpd/ft)	Sample Depth (ft)	Comments
894.66 - 884.66	21.4	3,530	70 - 80	Duration = 45 minutes
866.66 - 856.66	21.4	13,450	98 - 108	Duration = 45 minutes
839.66 - 829.66	21.8	8,990	125 - 135	Duration = 45 minutes

MW-7

Elevation of Test Interval (ft MSL))	Pump Rate Q (gpm)	Transmissivity T (gpd/ft)	Sample Depth (ft)	Comments
949.56 - 939.56	~0	-	65 - 75	Little water
919.56 - 909.56	5	80	95 - 105	Duration = 15 minutes
899.56 - 889.56	2.5	30 12	115 - 125	Duration = 45 minutes

The results of the packer pump tests are summarized in Table 3-7; time-drawdown graphs and calculations are presented in Appendix B. The calculated transmissivity (T) values ranged over approximately three orders of magnitude from 12 gpd/ft in MW-7 (test interval elevation: 890 feet to 900 feet above MSL) to 26,400 gpd/ft in MW-3 (test interval elevation: 890 feet to 900 feet and 910 feet to 920 feet).

MW-1 displayed moderate transmissivity values ranging from 830 gpd/ft to 2,100 gpd/ft for test interval elevations: 899 feet to 909 feet and 865 feet to 875 feet, respectively. MW-2 displayed moderately low transmissivity values ranging from 180 gpd/ft to 1,980 gpd/ft (test interval elevation: 875 feet to 900 feet). Five "dry" zones were encountered at depth between the 720-foot to 860-foot elevations. MW-3 displayed the largest transmissivity values ranging from 10,100 gpd/ft to 26,400 gpd/ft though a "dry" zone was encountered at the 870-ffoot to 880-foot elevation. MW-5 displayed T values ranging from 2,800 gpd/ft to 6,750 gpd/ft and a dry zone at the 843-foot to 853-foot elevation; MW-6 displayed moderately high T values (3,530 gpd/ft to 13,450 gpd/ft) and no dry zones were encountered. MW-7 displayed the smallest T values (12 gpd/ft to 130 gpd/ft) with a dry zone at the 940-foot to 950-foot elevation.

In general, there appears to be little correlation across wells between the magnitude of the T value and the elevation of the test interval. The transmissivity values represent fracture variability rather than specific fracture-depth relationships.

Water samples were taken for selected test intervals during the packer-pumping tests. The purpose of this sampling was to obtain some information on the variation in concentration of contaminants with depth (see Appendix E). The results of these analyses indicate that there is a relationship between concentration and depth for some chemical constituents. However, the results provide only an indication since they were not able to be validated using QA/QC procedures.

3.6.2 Aquifer Pump Tests

Aquifer pump tests were performed at the Berks Sand Pit Site during the months of December 1987 and February 1988. An abbreviated pump test was conducted on December 8, 1987 to obtain preliminary estimates of the hydrogeologic parameters at the site. The estimated parameters (primarily the transmissivity) were subsequently used to design additional pump tests. Three additional (successful) pump tests were performed in February 1988. The purpose of these tests were to:

- Confirm the results of the December test.
- Obtain a better estimate of the hydraulic properties of the aquifer (primarily transmissivity).
- Qualitatively detect any gross anisotropies or anomalous responses occurring within the system.

For all tests, the discharge water was pumped to the treatment area where it was monitored with an OVA. If the headspace monitoring by the OVA showed readings above an action level established by PADER/EPA of 3 ppm above background, the discharge water was passed through Cansorbs® (carbon adsorption units), overflow was discharged into storage pools and treated after the termination of the test. The pump, electrical wiring, and discharge lines were decontaminated with Alconox and water and rinsed with distilled water prior to being placed in the wells. A summary of all pump tests is given in Table 3-8.

The abbreviated pump test (December 1987) was performed with MW-2 as the pumping well. A submersible Franklin pump rated at 50 gpm was set at approximately 100 feet below the top of the casing in MW-2. The actual pumping rate (40 gpm) was determined using a calibrated 55-gallon drum and stopwatch. Water levels were measured by hand in all MW, SW, and ERT wells, though measurements were concentrated in MW-1, MW-2, MW-4, MW-5, MW-9, SW-1, and SW-3. The duration of the pump test was 376 minutes (6.3 hours) with a maximum drawdown in MW-2 of 39.18 feet. A recovery test was started immediately at the termination of the pump test. Water levels were measured by hand in MW-1, MW-2 and MW-9 for 120 minutes (2 hours); approximately 96 percent recovery was achieved.

The pump test had to be terminated prematurely (after 6.3 hours) because of limited storage capacity at the treatment area. All of the pump discharge water was treated prior to release to the watershed. Headspace OVA readings of the discharge water before and after treatment were: for 0 to 5.5 hours the OVA readings were 1 ppm to 2 ppm above background before treatment and 0 ppm above background after treatment, and for 5.5 hours to 6.3 hours the OVA readings were 85 ppm to 90 ppm above background before treatment and 0.3 ppm above background after treatment. These values indicate that a mass of contaminated water was

Table 3-8

BERKS SAND PIT
SUMMARY OF AQUIFER PUMP TEST CONDITIONS

Test	Date Performed	Pumping Well	Approximate Pumping Duration (hours)	Approximate Pumping Rate (gpm)	Maximum Drawdown (ft)	Approximate Recovery Duration (hours)	Percent Recovery	Comments
Abbreviated Test	12/8/87	MW-2	6.3	40	39.18	2.5	96.5	(1)
Test #1	2/23/88	MW-1	24	27	15.28	11.5	88	
Test #2								
A	2/25/88	MW-7	1.25	28	85.43	3.3	-	(2)
B	2/25/88	MW-7	0.3	30-40	85.43	0.4	99	(3)
C	2/25/88	MW-7	0.5	--	8.72	--	-	(4)
Test #3	2/26/88	MW-7	12.3	8	29.11	3.7	98	Redesign of Test #2

(1) Shutdown due to limited water storage capacity.
(2) Excessive drawdown.
(3) Blew out discharge line - excessive drawdown.
(4) Discharge line frozen.

intercepted and extracted after approximately 13,000 gallons of water were pumped from MW-2. Approximately 2,000 gallons of highly contaminated water was removed from the aquifer. It should be noted that the contaminants were removed from the water to below the volatile organic emission action level of 3 ppm by the Cansorbs®.

The data from the abbreviated pump and recovery tests were analyzed by the Cooper and Jacob straight-line time-drawdown method, presented in Appendix C. A summary of the transmissivity and storativity values obtain from the Jacob straight-line method are given in Table 3-9. The transmissivities and storativities obtained from this evaluation are only order of magnitude values because:

- As with the packer tests, the assumptions inherent in the Jacob straight line method were not necessarily satisfied; however, this method generally yields order of magnitude estimates over a broad range of hydrogeologic conditions.
- There are small variations in the pumping rate (generally less than 10 percent) which could affect the transmissivity calculations.
- The test was terminated prematurely due to a lack of storage capacity at the treatment area.

Calculated transmissivity values for the abbreviated test ranged over approximately two orders of magnitude from 440 gpd/ft in MW-2 to 26,400 gpd/ft in MW-5 and from 9,600 gpd/ft in SW-1 to 75,430 gpd/ft in SW-3. The average transmissivity for MW-2 (2610 gpd/ft) appears to be lower than that for the other wells (see Table 3-9). This could indicate that MW-2 does not intercept a highly fractured zone. The low transmissivity values obtained for MW-2 could also be a result of the application of the Cooper-Jacob method to data from the pumping well. Another more probable explanation is that the transmissivity values obtained when a particular well is used as a pumping well are generally lower than when that well is used as an observation well. This is because well loss (head loss) tends to create a greater drawdown in the pumping well and, hence, a lower transmissivity value. MW-5 exhibited the largest T values indicating that this monitoring well is possibly located in a zone of increased fracture frequency.

Response (drawdown) to the pumping was reported in both MW-5 and SW-3 (about 350 feet from the pumping well) but not in ERT-1, ERT-2, SW-6, and SW-7 (all between 275 and

Table 3-9

BERKS SAND PIT
SUMMARY OF TRANSMISSIVITIES (T) STORATIVITIES (S) FROM THE ABBREVIATED PUMP TEST

Well	Cooper and Jacob Straight Line			Average Transmissivity (gpd/ft)
	T from Drawdown Data (gpd/ft)	S	T from Recovery Data (gpd/ft)	
MW-1	7,180	0.0012	12,070	9,630
MW-2	780 3,020 3,520	- - -	440 5,280	2,610
MW-4	8,590 31,060	0.0012 0.0012	-	19,830
MW-5	26,400 18,210	0.0004 0.0006	-	22,310
MW-9	5,870 9,600	0.009 0.0156	12,420 9,600 3,400	8,180
SW-1	13,890 9,600	0.005 0.0205	-	11,750
SW-3	75,430	0.0007	-	75,430

AR300070

450 feet from the pumping well). A zone of influence elongated in a northeasterly direction apparently developed. This suggests that there is a higher average transmissivity in the northeasterly direction which may represent a preferred flow direction.

Calculated storativities ranged from 0.0004 to 0.0205. These values are in the range of a confined (0.00001 to 0.001) or leaky confined aquifer.

Pump test No. 1 was performed in February 1988 with MW-1 as the pumping well. The same pump that was used for the abbreviated test was also used for pump test No. 1. The discharge rate, however, was reduced from 40 gpm to approximately 27 gpm. Water levels in MW-1, MW-2, MW-7, MW-9, SW-1 and SW-4 were measured by pressure transducers and recorded by three two-channel In-Situ Hermit Data Loggers. Time-drawdown data was downloaded from the data loggers to magnetic floppy disk and was graphed on a personal computer using Golden Software's Grapher package. Water levels in ERT-1, ERT-2, and SW-6 were measured by hand. Monitoring wells MW-4, MW-6, MW-8, and ERT-3 were occasionally monitored by hand to obtain a qualitative indication of the extent of drawdown. A recovery test was started immediately at the termination of the pump test. Data for the recovery test was recorded in the same manner as that for the pump test. The duration of pump test No. 1 was 24 hours and that of recovery test No. 1 was 11.5 hours.

The pump discharge water was initially released through aerators to the watershed. The quality of the water was monitored by taking headspace readings with an OVA. For the first 12 hours of the test, the OVA readings ranged from 0.2 ppm to 0.8 ppm above background. The OVA malfunctioned after 12 hours of use and all discharge water was subsequently routed through the treatment system (Cansorbs®) or stored in pools for later treatment.

One anomalous response was noted in MW-1. After pumping for about 18 hours the drawdown decreased by approximately 4.4 feet (i.e., the water level rose by 4.4 feet). A similar response, though of less magnitude, occurred in MW-2, MW-7, MW-9, and SW-1. Two possible explanations are:

1. There was a temporary pump malfunction: This is possible though no malfunction or variation in flow rate was observed in the field. The pump discharge rate was measured hourly.

2. Washing (removing) of fracture fillings or "dams."

A satisfactory explanation for this anomaly has not yet been determined.

Data from pump test No. 1 was evaluated by Jacob's straight-line method,the Hantush Modified Type Curve Matching Technique, and a distance-drawdown technique as described in Appendix C. Semi-log plots for the Jacob straight-line method, log-log plots for the Hantush method, supporting calculations and a summary description of all three methods are presented in Appendix C. A summary of transmissivity and storativity values calculated by these methods is given in Table 3-10a and a summary of the values from the distance drawdown calculations is given in Table 3-10b.

The transmissivity values calculated by the Jacobs straight-line and Hantush are, in general, comparable and range over approximately two orders of magnitude from 1,350 gpd/ft in MW-9 to 32,400 gpd/ft in MW-7 and from 9,140 gpd/ft to 119,000 gpd/ft in SW-1.

The transmissivity values calucated from the distance-drawdown relationship (Table 3-10b) are generally lower than the transmissivities calculated from the other two methods (Table 3-10a). However, it appears that for times greater than about 100 minutes, the transmissivity values from the Jacob method begin to approach those for the distance-drawdown method. This suggests that if pump test No. 1 had been conducted for a longer period of time (approaching steady state), the transmissivity values calculated from both the Jacob and Hantush methods would have approached those from the distance-drawdown method. Thus, the transmissivities calculated from the time-drawdown methods after a time of 100 minutes, and from the distance-drawdown method are probably the most representative of actual aquifer conditions.

MW-2 displayed T values similar to those calculated for the other MW wells indicating that the low T values calculated for the abbreviated test are at least in part attributable to the method of evaluation and well loss (head loss in the pumping well) rather than the lack of fractures. It should also be noted that the T values for MW-1 (the pumping well) for test No. 1 appear to be slightly smaller than the values for the other MW wells. This indicates that well loss in the pumping well is the primary cause for the apparently small transmissivity values noticed in the pumping wells.

Transmissivity calculations by the Hantush method indicate that confined ($\beta = 0$) and leaky confined (β = 0.1 - 0.2) conditions exist in the bedrock aquifer. This is supported by the

Table 3-10a

BERKS SAND PIT
SUMMARY OF TRANSMISSIVITIES (T) AND STORATIVITIES (S)(1) FROM PUMP TEST NO. 1

Well	Cooper and Jacob Straight Line			Hantush Modified Type Curve		Average Transmissivity(3)
	T Drawdown	S Drawdown	T Recovery	T Drawdown	T Recovery	
MW-1	840 3,200 1,680	- - -	2,380 5,700 4,460(2)	- - -	2,380	2,950
MW-2	6,200 4,900(2) 3,360(2)	0.0003 0.0013 0.0035	8,390 14,300 7,920(2)	4,600 19,300	10,700	8,260
MW-7	32,400 17,000(2) 9,630(2)	0.0015 0.0013 0.0022	22,300 12,700(2)	11,500	20,600	16,150
MW-9	2,200 5,100 1,980(2)	0.0002 0.0001 0.0011	8,390 3,320 6,790 4,750(2)	1,350 5,160	6,730	4,510
SW-1	119,000 23,000(2) 9,140(2)	0.0015 0.0332 0.0370	29,700(2)	103,000	30,900	45,330
SW-4	47,500(2) 13,700(2)	0.0232 0.0440	37,500(2)	34,400	51,600	31,220

(1) Multiple values derived from multiple segments of line or curve. Transmissivity units are gallons/day/foot; storativity is dimensionless.
(2) Denotes transmissivity values for a time greater than 100 minutes.
(3) Average transmissivity values include values calculated by Cooper and Jacob straight-line method, Hantush Modified Method, and Distanct-Drawdown Method.

Table 3-10b

BERKS SAND PIT
SUMMARY OF DISTANCE-DRAWDOWN CALCULATIONS FOR PUMP TEST NO. 1 AT 1,000 MINUTES

Well	Distance from MW-1 (ft)	Transmissivity (gpd/ft)
MW-2	77	2,960
MW-7	335	3,050
MW-9	77	3,880
SW-1	120	2,580
SW-4	140	2,610

storativities calculated by the Jacob method for the MW wells which ranged from 0.0001 to 0.0035. The SW wells, on the other hand, displayed much larger T and S values indicating that the weathered overburden is highly transmissive and under leaky confined conditions.

The distance-drawdown calculations between MW-1 and the other wells indicate that there is no well defined, preferred flow path. There was no response in the hand monitored wells ERT-1, ERT-2, SW-6, and MW-8 but there was a response in MW-4, MW-6, and ERT-3.

Pump test No. 2 was also performed in February 1988 with MW-7 as the pumping well. The same procedures and equipment used for pump test No. 1 also were used for pump test No. 2. Monitoring wells MW-1, MW-3, MW-7, SW-4, RW-2, and RW-3 were monitored with transducers and dataloggers. Pump test No. 2 is subdivided into three parts: 2A, 2B, and 2C. Pump test 2A was run in the same manner and with the same equipment as pump test No. 1. The discharge rate for test 2A was approximately 28 gpm. The duration of the pump test was 1.25 hours and that of the recovery test was 3.3 hours. After approximately one hour of pumping, MW-7 displayed a drawdown of approximately 85 feet (to the level of the pump intake). The pump test was terminated after 1.25 hours of pumping because of excessive drawdown. Recovery data from pump test No. 2-A is plotted in Appendix C. The discharge line from the pump was changed from a 2-inch I.D. line to a 1-inch I.D. line to decrease the pumping/discharge rate.

The pump test run with this configuration, i.e., a 1-inch I.D. discharge line, is referred to as pump test No. 2B. Just after the start of this test, a frozen discharge line ruptured causing rapid, excessive drawdown on the order of 85 feet in the pumping well, MW-7. This test was terminated after approximately 20 minutes of pumping. Drawdown data from this test is plotted in Appendix C, but it is of questionable utility.

A third attempt at running the pump test was made with the above configuration (i.e., a 1-inch discharge line) and is referred to as pump test No. 2C. No discharge was noted at the outlet of the discharge line after the pump had been turned on. It was determined that the discharge lines were frozen and were not transmitting water.

Data obtained from pump test No. 2 is of questionable quality and will not be discussed in detail. Calculated transmissivity values for recovery test 2A and pump test No. 2B are presented in Table 3-11 with supporting graphs and calculations in Appendix C.

Table 3-11

BERKS SAND PIT
SUMMARY OF TRANSMISSIVITIES (GPD/FT) FROM PUMP TEST NO. 2*

Well	Cooper and Jacob Straight Line		Hantush Modified Type Curve		Average Transmissivity
	Drawdown	Recovery	Drawdown	Recovery	
MW-7	40	180 230 1,500	480	190	440

*Transmissivity estimates from drawdown data are based on pump test No. 2B.

Transmissivity estimates from recovery data are based on pump test No. 2A. The estimates from the recovery data are more reliable than the estimated from the drawdown data because there was a better control on the pumping rate in test No. 2A.

Pump test No. 3 is a redesign of pump test No. 2. As in test No. 2, MW-7 was chosen as the pumping well, and MW-1, MW-3, MW-7, SW-4, RW-2, and RW-3 were monitored with dataloggers and transducers. A one-half horsepower Grundfus submersible pump with a maximum pumping rate of 15 gpm was used instead of the Franklin pump, and a 3/4-inch discharge line was used instead of a 1-inch discharge line. Flow rates and water levels were measured as in pump test No. 1. The duration of pump test No. 3 was approximately 12.3 hours with a measured discharge rate of 8 gpm. The maximum drawdown in MW-7 was 29.11 feet. Recovery measurements, initiated immediately after the termination of pumping, were made for approximately 3.7 hours until 98 percent recovery was attained.

All discharge water from MW-7 was piped to the on-site treatment system and either passed through the Cansorbs® or stored in pools for later treatment. Headspace OVA readings taken of the discharge water are as follows: from 0 to 4 hours the initial headspace OVA readings were 90 ppm to 100 ppm above background with readings quickly (<15 seconds) falling to approximately 0.5 ppm; from 4 hours to 6.5 hours the initial headspace OVA readings were steady at 100 ppm to 300 ppm above background; from 6.5 hours to 12.3 hours the initial headspace OVA readings were about 90 ppm to 100 ppm above background with readings quickly (<15 seconds) dropping to approximately 0.5 ppm. A total of approximately 5,900 gallons of contaminated water was pumped from the ground and treated during this test.

Data from pump test No. 3 was evaluated with Jacob's Straight-Line Method and the Hantush Modified Type Curve Method as described in Appendix C. Graphs and supporting calculations are presented in Appendix C. A summary of transmissivity and storativity values is presented in Table 3-12.

The transmissivity values calculated by the two different methods are comparable and range over approximately two orders of magnitude from 50 gpd/ft in MW-7 to 19,200 gpd/ft in SW-4. Three storativity values were calculated with a range of 0.0008 to 0.0030 which indicates confined to leaky confined conditions.

The lowest transmissivities were encountered in MW-7, the pumping well. Although the low values may in part be derived from the method of analysis and well loss, the large drawdown (approximately 30 feet) with a low pumping rate (approximately 8 gpm) indicat[illegible] is indeed located in a relatively low transmissivity zone; i.e., MW-7 probably does not intercept a zone of concentrated fractures, or if it does intercept a fracture zone, then those

Table 3-12

BERKS SAND PIT
SUMMARY OF TRANSMISSIVITIES (GPD/FT) AND STORATIVITIES FROM PUMP TEST NO. 3

Well	Cooper and Jacob Straight Line			Hantush Modified Type Curve		Average Transmissivity
	T Drawdown	S Drawdown	T Recovery	T Drawdown	T Recovery	
MW-1	6,600	0.0008	11,100	4,830	8,330	7,720
MW-3	10,100 5,700	0.0029 0.0030	15,100	3,990	13,700	9,720
MW-7	140	- - -	210 90 700	80	50	210
SW-4	(1)	-	19,200	(1)	(1)	19,200
RW-2	(1)	-	(1)	(1)	(1)	-
RW-3	(2)	-	(2)	(2)	(2)	-

(1) Response unreliable; Δs low.
(2) Well showed no response.

fractures are probably not highly weathered. This is, however, contrary to the transmissivity values calculated for MW-7 from pump test No. 1 data (16,150 gpd/ft). The large average transmissivity calculated from pump test No. 1 is possibly biased by using early time data for the calculations. As stated in the discussion for pump test No. 1, it is thought that the late time data (Table 3-10a) and the distance-drawdown data (Table 3-10b) yield the most representative transmissivity values for MW-7.

SW-4 exhibited the largest transmissivity. This suggests the possibility of a more transmissive flow regime in the overburden and supports the observations made in pump test No. 1.

No response was noted in RW-2 or RW-3 though a response was noted in MW-1 and MW-3, both a greater distance from the pumping well than the two residential wells. This suggests that a better hydraulic interconnection exists between MW-7 and the two MW wells than between MW-7 and the two RW wells. It should be noted that all five of these wells are reported to extend between 110 feet and 150 feet below the ground surface and into the fractured bedrock.

A summary of the observations made during the aquifer pump tests follows:

- Average transmissivities for MW-7 (Table 3-13) suggest that this well is located in a moderately fractured zone. However, observations during pump tests 2 and 3 indicate that MW-7 is located in a zone of reduced transmissivity. Transmissivity values calculated by the distance-drawdown method (Table 3-10b) are thought to be most representative of the actual conditions in MW-7.

- The shallow aquifer monitored by the SW wells appears to be under semi-confined conditions.

- The shallow aquifer monitored by the SW wells appears to have a larger average transmissivity than the fractured bedrock aquifer (see Table 3-12).

- The fractured bedrock aquifer monitored by the MW wells appears to be under confined to leaky confined conditions. The saprolite may be acting as a confining unit.

Table 3-13

BERKS SAND PIT
AVERAGE TRANSMISSIVITIES (GPD/FT) AND STORATIVITIES

Well	T Average(1)	S Average(2)	T Average(3)	All Average Transmissivity(4)
MW-1	5,520	0.001	5,180	5,440
MW-2	5,090	0.0017	11,530	6,380
MW-3	10,300	0.0030	8,850	9,720
MW-4	19,830	0.0012	-	19,830
MW-5	22,310	0.0005	-	22,310
MW-7	7,160	0.0017	5,480	6,650
MW-9	5,950	0.0053	4,410	5,660
SW-1	29,560	0.0196	66,950	37,870
SW-3	75,430	0.0007	-	75,430
SW-4	24,100	0.0336	43,000	29,500

(1) Average transmissivities calculated from Cooper and Jacob Straight-Line Method and Distance-Drawdown Method.
(2) Average storativities calculated from Cooper and Jacob Straight-Line Method.
(3) Average transmissivities calculated from Hantush Modified Method.
(4) Average transmissivities calculated from Cooper and Jacob Straight-Line Method, Distance-Drawdown Method and Hantush Modified Method.

- There appears to be little direct hydraulic connection between MW-7 and RW-2 and RW-3.

- The distance-drawdown calculations between MW-1 and the other wells indicate that there is no well defined, preferred flow path.

In general, the aquifer tests suggest that there are two flow regimes, one in the overburden and weathered rock, and one in the fractured bedrock each with its own aquifer characteristics.

3.7 Geophysical Investigation

Four geophysical techniques were used to aid in the characterization of the Berks Sand Pit Site. Borehole geophysical surveys were performed in all of the MW monitoring wells and in RW-5. Surface seismic refraction surveys were performed along two traverses, one striking NW-SE and the other NE-SW. Two cross-hole seismic surveys were performed at selected monitoring wells and one vertical seismic imaging or tomography survey was performed at MW-1, MW-2 and MW-9. A description of these geophysical surveys follows.

3.7.1 Borehole Geophysical Logging

Borehole geophysical logging was performed in all of the MW wells and in RW-5 in September 1987. The survey, performed by Appalachian Coal Surveys, provided two suites of geophysical logging of lithology and groundwater.

- Lithology Suite - Caliper, Natural Gamma, Density and Resistivity.

- Groundwater Suite - Spontaneous Potential, Fluid Temperature, Fluid Conductivity, Resistivity, and Neutron.

Verticality surveys were also conducted at all MW wells and at RW-5.

The purpose of the borehole geophysical logs was to confirm the borehole drilling logs, to delineate major fractures or fracture zones, to identify fluid inflow and outflow zones and to provide a vertical control on the location of the wells.

The following is a brief description of the logs generated and the expected benefit of each. The borehole geophysical logs are presented in Appendix D.

- Temperature log - This log continuously measures the temperature of the borehole fluid throughout the hole. A sudden temperature drop usually indicates groundwater inflow points.

- Three Arm Caliper log - The three arm caliper log provides a linear trace of changes in hole diameter. This gives an indication of the relative hardness of the bedrock. More importantly, the caliper log indicates, as a sharp peak, any open fractures within the rock units.

- Neutron log - The neutron log uses a low level radioactive source to generate neutrons which are emitted into the formation. Some of the neutrons are captured by hydrogen atoms. A counter measures the amount of backscatter of neutrons and the amount of capture by the formation. The neutron log responds primarily to water contained within the formation and gives an indication of water levels and inflow/outflows in the borehole.

- Spontaneous Potential (SP) log - This log records the naturally occurring electrical current flow present in the ground by measuring the difference in electrical potential between a moving electrode down the hole and a stationary electrode at the surface. Peaks generally occur when pervious strata are encountered.

- Wall (Contact) and Single Point Resistivity logs - These logs measure the differences in resistivity throughout the borehole. These resistivity logs are used primarily to measure lithologies and moisture contents.

- Natural Gamma log - The natural gamma log measures the natural radioactivity of a formation. Different rocks emit different amounts of gamma rays in proportion to the concentration of radioactive elements within the rock. The natural gamma log is used to delineate lithologic changes, primarily beds of high shale and clay content, occurring in the borehole.

- High Resolution Gamma-Gamma Density log - This log measures scattered gamma rays emitted from a radioactive source. The gamma rays are emitted to the formation and collide with electrons in the formation. At each collision, the gamma ray loses some energy to the electron. These scattered gamma rays are counted by a detector a fixed distance from the gamma ray source. Differences of counted gamma rays reflect changes in the density of the formation.

- Fluid Conductivity - This log measures the conductivity of the inhole liquid between electrodes mounted in a probe. The log gives a continuous record of the conductivity of the borehole fluids. This log is helpful in estimating the character of the groundwater in the adjacent rock.

- Verticality logs - Verticality is a measure of borehole straightness or plumbness. Verticality logs are used to determine the exact location of a borehole in the subsurface.

During the geophysical logging, care was taken to prevent cross contamination in the wells. The downhole tools were scrubbed with soap and water and rinsed with distilled deionized water. Decontamination of all downhole tools was performed prior to use at each well.

The first suite of borehole logging, the groundwater suite, consisted of spontaneous potential, temperature, conductivity, resistivity and neutron logs. The groundwater suite was performed on all of the MW wells. A summary of the inflow zones for each well is given in Table 3-14. The temperature log was relatively constant in all wells except MW-1. This suggests that there is significant vertical mixing of the water in each well and, therefore, vertical hydraulic gradients. The magnitude of these gradients has not been determined.

The second suite of borehole logging, the lithology suite, consisted of caliper, gamma, density and resistivity logs. The lithology suite was performed on all of the MW wells and on RW-5. This suite identified three lithologies in the boreholes: feldspar rich granite/gneiss, feldspar-poor granite/gneiss, and clay. The high resolution density, caliper, and both types of resistivity logs (wall and single point) were used to identify fracture zones which intersected the boreholes. Boreholes MW-2, MW-3, MW-6, and MW-7 showed a high fracture density (greater than 0.1 fractures/foot) and boreholes MW-1, MW-4, MW-5, MW-8, and MW-9 showed only a few fractures. The number of fractures identified is not necessarily related to the hydraulic conductivity of the rock mass since some fractures could be closed or clay filled. Fractures with similar logged characteristics were correlated between MW-1, MW-2, and MW-9 (see Appendix D) and defined a north-northwest strike direction with a shallow to

Table 3-14

BERKS SAND PIT
SUMMARY OF BOREHOLE FLOW ZONES AND FRACTURE ZONES

MW-1			MW-3		
Depth (ft)	Inflow Zone Depth (ft)	Fracture Zone Depth (ft)	Depth (ft)	Inflow Zone Depth (ft)	Fracture Zone Depth (ft)
50			50	51 - 57	52 - 55, 56, 59 - 60
					60 - 61, 62 - 63, 69
				76 - 80	74 - 75, 78 - 79
	83 - 90	81 - 82		80 - 84.5	82 - 84
	90 - 96			96.5 - 100	98 - 99
100	107 - 110		100	100 - 102	109 - 110
	110 - 116	111 - 114			
	119 - 130	128 - 129			
	130 - 140				138 - 139
	140 - 150			145 - 150	
150			150	150 - 153	

Table 3-14

BERKS SAND PIT
SUMMARY OF BOREHOLE FLOW ZONES AND FRACTURE ZONES
-continued-

MW-2					
Depth (ft)	Inflow Zone Depth (ft)	Fracture Zone Depth (ft)	Depth (ft)	Inflow Zone Depth (ft)	Fracture Zone Depth (ft)
50	57 - 60			182 - 190	
	60 - 70	60 - 61, 64 - 65, 67 - 68		190 - 196	197 - 198
	70 - 80	74 - 75, 76 - 77, 78 - 79	200		209 - 210
	80 - 90	86 - 87			215 - 216
	90 - 100	96 - 97		224 - 230	229 - 230
100	100 - 107	102 - 104		230 - 240	234 - 235
				240 - 248	240 - 241, 246 - 247
	122 - 130	121 - 123	250		251 - 253, 254 - 255, 259 - 260
	130 - 137	129 - 131			262 - 263
					275 - 276
150		151 - 152, 157 - 158		284 - 290	
				290 - 300	
		171, 173 - 174	300	300 -	

Table 3-14

BERKS SAND PIT
SUMMARY OF BOREHOLE FLOW ZONES AND FRACTURE ZONES
-continued-

MW-4			MW-5		
Depth (ft)	Inflow Zone Depth (ft)	Fracture Zone Depth (ft)	Depth (ft)	Inflow Zone Depth (ft)	Fracture Zone Depth (ft)
50			50	50 - 60	
				60 - 67	
				88 - 90	
				90 - 93	
				107.5 - 110	
100			100	110 - 114.5	
	133 - 140				
	140 - 145			146 - 150	
150			150	150 -	

Table 3-14

BERKS SAND PIT
SUMMARY OF BOREHOLE FLOW ZONES AND FRACTURE ZONES
-continued-

MW-6			MW-7		
Depth (ft)	Inflow Zone Depth (ft)	Fracture Zone Depth (ft)	Depth (ft)	Inflow Zone Depth (ft)	Fracture Zone Depth (ft)
30			30		36 - 38
50			50		55 - 57
	66 - 70	68 - 70			
	70 - 75	71 - 73, 79 - 80			71 - 72, 78 - 79
		80 - 81		87 - 90	81 - 83
	98 - 100	98 - 99		90 - 100	99 - 100
100	100 - 102	102 - 103, 107 - 108	100	100 - 107.5	105 - 107
	106 - 120	115 - 117			115 - 116
	120 - 125	126 - 129			122 - 123, 129 - 130
	136 - 140	134 - 136			132 - 133
	140 - 150			149 - 150	
150	150 -		150	150 -	

Table 3-14

BERKS SAND PIT
SUMMARY OF BOREHOLE FLOW ZONES AND FRACTURE ZONES
-continued-

MW-8			MW-9		
Depth (ft)	Inflow Zone Depth (ft)	Fracture Zone Depth (ft)	Depth (ft)	Inflow Zone Depth (ft)	Fracture Zone Depth (ft)
30	32 - 40	35 - 36	30		
	40 - 48	44 - 45			
50			50	55 - 60	
				60 - 68	69 - 70
				74 - 80	
				80 - 88	
		95 - 96			95 - 96
100			100		
		115 - 116			
				125 - 130	
		138 - 140		130 - 140	137 - 138
	140 - 150			140 - 150	
150			150	150 -	

moderate dip to the east-northeast. Lithologic correlations based on natural gamma and density logs also defined a shallow northeast dip. The geophysical logs for all the boreholes are presented in Appendix D.

Geophysical logs from MW-2 show a very highly fractured zone from just below the casing (57 feet) to 104 feet. Below 104 feet the rock appears to be relatively competent with a few widely spaced fractures. Neutron and resistivity logs indicate that this highly fractured zone is water bearing. Analysis of logs from the closest adjacent holes (MW-1 and MW-9) revealed no similar highly fractured zone in either borehole. However, the fractures that were observed in wells MW-1 and MW-9 appear to be water bearing.

Fractures identified in boreholes MW-3, MW-6, and MW-7 occur relatively evenly spaced throughout the interval logged. The fractures appear to be water bearing and commonly occur with increased frequency near lithologic boundaries.

Zones of high natural gamma readings were observed in boreholes MW-1, MW-6 and MW-9. Borehole MW-3 showed consistently high natural gamma readings throughout the hole. These zones of high natural gamma readings are indicative of alteration of the rock to clay and/or mica. These zones tend to be softer, having a consistently larger borehole diameter, and commonly occur adjacent to significant fractures. The fractures provide a conduit for fluids to enhance the alteration process. Extensive alteration is observed in MW-1 and MW-6 in areas where fractures are present.

A summary of specific fractures zones for the MW wells is given in Table 3-14. Complete borehole geophysical logs are given in Appendix D.

3.7.2 Surface Seismic Refraction Survey

A surface seismic refraction survey was performed by Weston Geophysical, Inc., in March and April, 1988. The survey was performed along two traverses to determine the depth to bedrock and to delineate deeply fractured or weathered zones. The survey was first performed along a 600-foot SE-NW traverse following the R-4/R-5 property line. This traverse is thought to be perpendicular to the expected strike of the bedrock. The second traverse was a NE-SW trending line, 800 feet long and centered approximately around MW-1. This line is parallel to the expected strike of the bedrock. The location of these two traverses is shown in

Figure 3-11. Complete results of the surface seismic refraction survey and a description of field and analytical procedures are given in Appendix D.

The interpreted seismic refraction profiles as presented on Figure 2 of Appendix D describe a complex subsurface condition with numerous lateral and vertical changes in seismic layering and seismic velocity values. Generalized boring logs for drill holes adjacent to the seismic lines also are shown on the seismic profiles. In general, the seismic refraction data and test borings are in good agreement.

The near surface overburden materials exhibit a wide variation in thickness ranging from 2 feet to as great as 32 feet. This near surface material has a velocity of 1600 ft/sec to 1800 ft/sec except near the southeast end of Line 1 where a lateral increase in velocity to 3800 ft/sec was detected. Test borings indicate that this near surface material is a combination of soil and saprolite; the 2800 ft/sec material is described as mostly saprolite. Underlying the near surface overburden material is a material with a velocity of 4000 ft/sec to 5000 ft/sec identified by the test borings as weathered bedrock. This layer ranges in thickness from 20 feet to 40 feet throughout most of the site area.

In general, the velocity of the competent bedrock as determined from surface seismic refraction data is 13,000 ft/sec to 14,000 ft/sec in the northeasterly strike direction. As expected, the strike velocity is slightly higher than the 12,000 ft/sec to 13,000 ft/sec velocity measured in the cross strike direction. Significant, local lateral velocity variations in the bedrock also were observed. Two significant low velocity bedrock zones with an estimated bedrock velocity of 8000 ft/sec to 10,000 ft/sec were identified; they are located on Line 1 between Stations 2+10 and 3+40 and on Line 2 between Stations 5+00 and 5+80 (see Appendix D for details). These low velocity zones are indicative of deeply weathered and fractured bedrock. The low velocity zone identified on Line 1 appears to be quite extensive, both laterally and vertically. A fractured bedrock zone with a significant vertical extent is also indicated by boring MW-2.

3.7.3 Cross-hole Seismic Refraction Survey

A cross-hole seismic refraction survey was performed by Weston Geophysical, Inc. in March and April, 1988 to measure the velocity distribution in the bedrock and to delineate possible fractured or weathered zones.

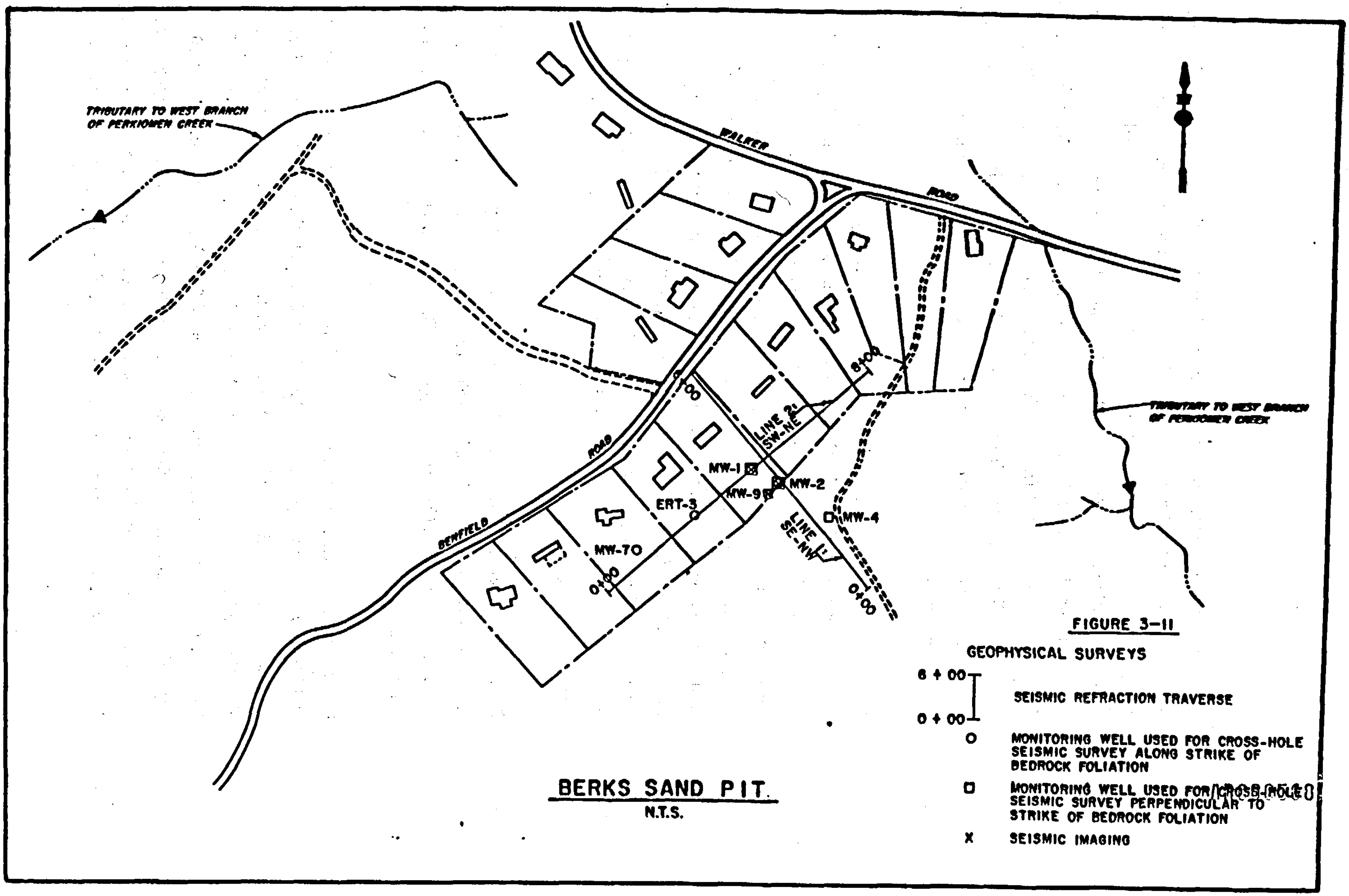


FIGURE 3-11

BERKS SAND PIT
N.T.S.

The cross-hole seismic study was performed utilizing existing wells at the site. The cross-hole program involved a network of geophones placed at different depths in several wells located along two primary sections (Figure 3-11). One section was oriented along the strike of the bedrock foliation (SW-NE) using wells MW-7, ERT-3, MW-1 and MW-2. Small shots (blasting caps) were used as the seismic source originating first from MW-7 and then from MW-2. Another section, oriented from northwest to southeast, utilized wells MW-1, MW-2, MW-9 and MW-4. Shots were set off first in MW-4 and then in MW-1. In these tests, geophones were spaced in the receptor wells to a depth of 150 feet where possible to provide data on deep bedrock conditions.

Measurements were made using geophones containing three orthogonal elements, one vertical and two horizontal. Seismic energy was generated in one hole and detected by geophones in other holes, usually with the geophones and seismic energy source at the same elevation. Since the borings are separated by varying distances, interchanging the seismic energy source and detectors yields different combinations of shot to detector distances, adding data points for velocity control. Velocity is the direct distance traveled divided by the travel time. On a time-distance plot, velocity lines drawn through the individual arrival times tie to time zero at the energy source confirming that the seismic waves have propagated through the same velocity layer. A further discussion of the cross-hole method of investigation is included in Appendix D.

Cross-hole velocities of the bedrock were measured both parallel and perpendicular to the regional northeast strike of the bedrock. The measured cross-hole velocity values are shown on the seismic profiles (Figure 2 of Appendix D) and are presented in tabular form on Table 1 of Appendix D.

In the northeast strike direction the bedrock velocity is observed to increase from 13,000 ft/sec to 15,000 ft/sec at an approximate elevation of 872 feet, the deepest strike direction velocity measurement elevation. Across strike where the velocity measurements extended to an elevation 826 feet, the velocity of the bedrock is observed to increase from 13,000 ft/sec to 16,000 ft/sec at an approximate elevation of 850 feet and then to 18,000 ft/sec at an approximately elevation of 826 feet. These higher velocities in the 15,000 ft/sec to 18,000 ft/sec range are typical of a sound and competent bedrock, relatively massive, and containing few if any weathered and/or fractured zones of significance to groundwater movement.

3.7.4 Vertical Well Logging (Tomography)

A vertical well imaging (tomography) survey was performed by Weston Geophysical, Inc. in March and April, 1988 to measure the three dimensional velocity distribution between three wells, MW-1, MW-2, and MW-9.

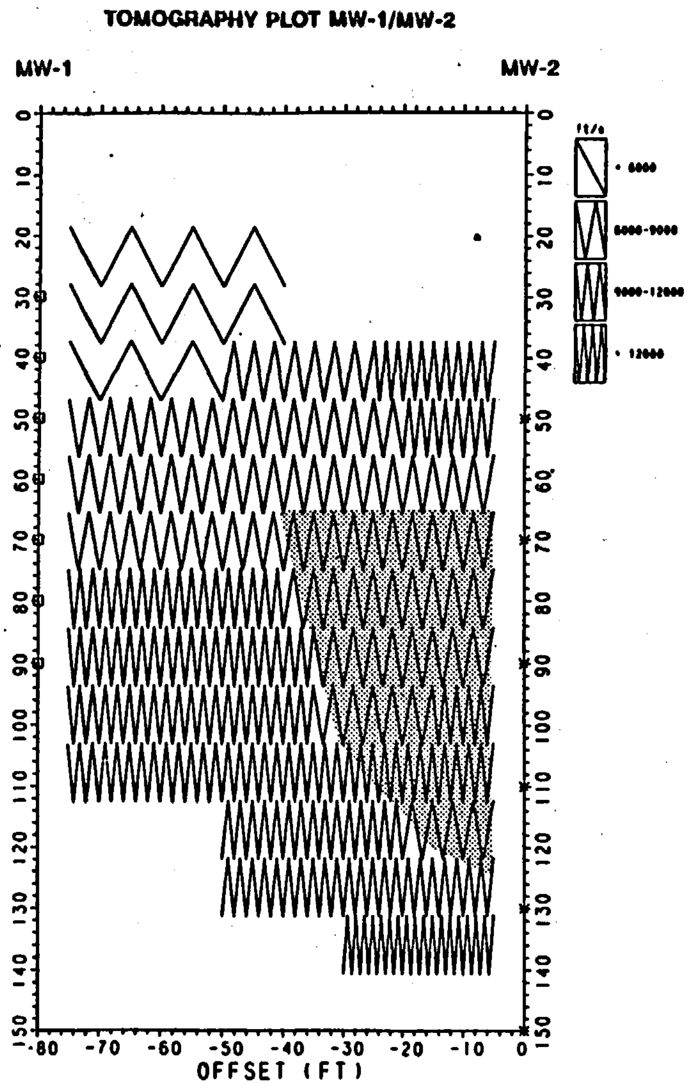
The borehole seismic imaging (tomographic modeling) was performed to identify zones of low, compressional wave seismic velocity indicative of extensive weathering and/or fracturing. The technique allows examination of materials outside the borehole in which the instrumentation is located, and also provides a tool for extrapolation of borehole log information. Seismic imaging thus extends the area which can be investigated by boreholes alone, permitting a more thorough investigation of the bedrock.

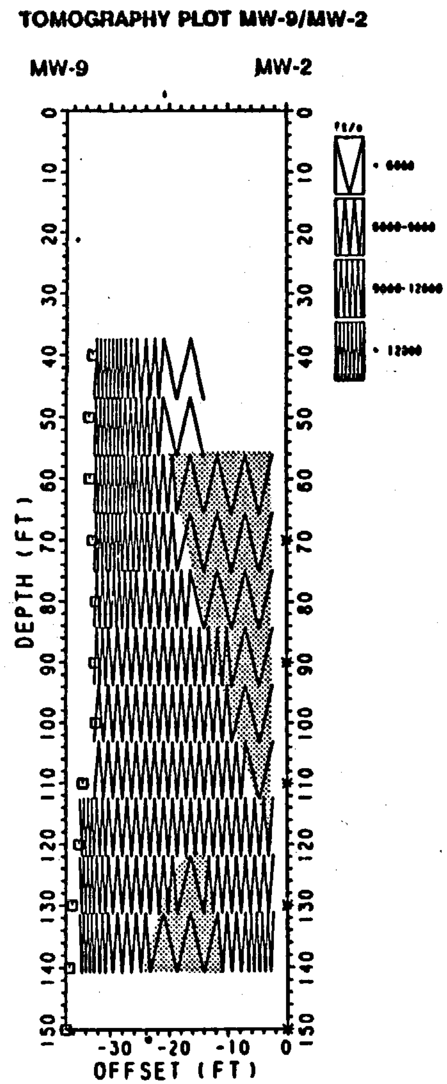
The seismic imaging survey was completed using existing wells (MW-1, MW-2 and MW-9). The seismic imaging survey involved a geophone streamer placed in a well, and seismic sources placed in an adjacent well. The geophone streamer contained 12 sensors spaced 10 feet apart and shots were placed at 20-foot vertical intervals.

Two tomographic profiles (representing two-dimensional velocity cross-sections) were generated. One trending southeast-northwest, between boreholes MW-1 and MW-2, another between boreholes MW-2 and MW-9 trending southwest-northeast. Exact shot point and receiver locations are shown with the tomographic contours on Figure 3-12.

The data were collected with the WesComp digital data acquisition computer and processing unit. Data processing was accomplished with Weston's proprietary tomographic software. A more comprehensive discussion of the seismic imaging method of investigation is included as Appendix D of this report.

Seismic imaging of bedrock velocity variations were completed between boreholes MW-1 and MW-2 and between boreholes MW-2 and MW-9. The results of the seismic imaging are presented in the form of tomography-velocity diagrams on Figure 3-12. The velocity values shown on the diagrams are not absolute velocity values but are relative values to describe changes in the velocity structure. Accordingly, the low velocity zones in the bedrock have been enhanced by shading on the tomography-velocity diagrams.





EXPLANATION

* ENERGY SOURCE LOCATION

▫ DETECTOR LOCATION

NOTE: SEISMIC VELOCITY VALUES ARE IN FEET/SECOND.

LOW VELOCITY BEDROCK ZONE

GEOPHYSICAL INVESTIGATION BERK'S SAND PIT LONGSWAMP TOWNSHIP, PENNSYLVANIA prepared for BAKER/TSA	SEISMIC IMAGING/ VELOCITY DIAGRAMS	
	Weston Geophysical	FIG. 3-12

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Below a depth of 60 feet, the depth to competent bedrock in the borehole area, the seismic imaging describes low velocity zones in the vicinity of borehole MW-2. The extent of this low velocity zone from MW-2 towards MW-1 and MW-9 is clearly shown on the tomography diagrams. The trend of the low velocity zone from the seismic imaging is consistent with the trend of the low velocity bedrock zone identified by the surface refraction measurements. The extent of this north-northwesterly trending zone is shown on Figure 4 of Appendix D.

3.8 Site Geology and Hydrogeology

This section provides an overview of the site geology and hydrogeology based on information gathered during the field investigation and previous investigations. Support for these summaries is presented in earlier sections of Chapter 3 and in Appendices A through D. Some additional data is also included.

3.8.1 Overview of Site Geology

The Berks Sand Pit is located in the Reading Prong Section of the New England Physiographic Province. Precambrian aged metamorphosed igneous, sedimentary and volcanic rocks comprise the highlands of the Reading Prong; the intermontane valleys are comprised of Cambro-Ordovician sediments consisting of limestone, dolomite, marble, and quartzite. Disseminated magnetite, and Cornwall-type magnetite deposits occur throughout the Reading Prong.

Lithologies and soil types in the vicinity of the site were determined from visual observation of split-spoon soil samples, NX cores, and drill cuttings obtained during the drilling program. The predominant lithology at the site is a variably fractured, tan to pink, medium grained granitic gneiss of Precambrian Age consisting of quartz, feldspar, hornblende, biotite, and chlorite. Grain size varies locally from fine to coarse and there is evidence of numerous quartz and feldspar-rich pegmatites throughout the area of investigation.

Zones of micaceous (biotite), hornblende and/or chlorite-rich granitic gneiss also were observed in the boreholes. These zones are generally comprised of light gray, green to black, biotite, hornblende or chlorite-rich granitic gneiss with abundant feldspar (plagioclase) and occasionally with abundant quartz. These zones tend to be foliated to well foliated, closely to very closely fractured and weathered.

Magnetite ore is present near the surface west of the site, at the Cha Gery Mine, and north of the site, at Rittenhouse Gap. Magnetite-rich pegmatites and massive magnetite was observed in three boreholes: MW-6, MW-7 and MW-8. Typical magnetite deposits in the Reading Prong consist of 30 percent to 50 percent iron, 1 percent to 2 percent sulfur as pyrite, or chalcopyrite and about 15 percent silica as actinolite, diopside, phlogopite, chlorite, serpentine and/or talc (3). The magnetite areas also tend to be be low in titanium, have minor amounts of calcite, dolomite, or ankerite, and may have notable amounts of copper and cobalt (3). Site-specific magnetite composition and associated mineralogy has not been determined.

The granitic gneiss is generally poorly foliated. However, the micaceous, hornblende and chlorite-rich zones tend to display well developed foliations. Foliation measurements by Woodward-Cycle Consultants (5) indicate a predominant strike of N45°E with dips ranging from 50° to 78° to the southeast. The orientation of a lineation measured by Ecology and Environmental, Inc. is N30°E. Foliation dips from the NX cores were determined to be approximately 70°. In general, the bedrock foliation, where present, strikes to the northeast and dips moderately to steeply to the southeast. (A summary of measurements of geologic structures is given in Table 3-15.)

The granitic gneiss is moderately to very closely fractured. Many fractures encountered in the boreholes contained chlorite filling and/or hematite staining on the fracture surfaces. Extensively weathered zones (possibly weathered fracture zones) were observed in MW-1, MW-3, MW-6, and MW-9.

Evidence from the borehole visual and geophysical logs indicate that fractures occur throughout the granitic gneiss but are concentrated in zones where mineralogical and/or grain size changes occur. High fracture frequencies (greater than 0.1 fractures/foot) were observed in MW-2, MW-3, MW-6 and MW-7, while relatively low fracture frequencies were observed in MW-1, MW-4, MW-5, MW-8, and MW-9. The maximum expected depth of significant fracture zones and weathered fractures, as determined from the cross-hole seismic velocity measurements, is approximately 150 to 200 feet below the ground surface.

Joint measurements along Gap Road, approximately one-fourth of a mile north of the site indicate northwesterly striking joints with dips ranging from 60° to 80° to the southwest (8). One measurement at the Cha Gery Mine indicated a joint with a strike of N60°E and a dip of 80°NW. The strike of the long axis of the Cha Gery and gap Road Mines is N10 [illegible] of the Cha Gery Mine shaft is 85°SE (9). The geophysical investigation defined fracture

Table 3-15

BERKS SAND PIT
SUMMARY OF MEASUREMENTS OF GEOLOGIC STRUCTURES

Location	Description	Strike/Dip	Source
Gap Road Mine	Joint	N10°W/80°W	(1)
Gap Road Mine	Joint	N70°W/60°SW	(1)
Gap Road Mine	Joint	N30°W/60°W	(1)
Gap Road Mine	Lineation	N30°E	(1)
Gap Road Mine	Long Axis of Mine	N10°E	(1)
ChaGery Mine	Joint	N60°E/80°NW	(1)
ChaGery Mine	Long Axis of Mine/Dip of Shaft	N10°E/85°SE	(1)
Outcrops	Foliation	N45°E/78°SE	(2)
NX Cores	Foliation	70° Dip	
NX Cores MW-2	Fractures Fractures Fractures	30° - 35° Dips 40° - 45° Dips 50° - 54° Dips	
NX Cores MW-4	Fractures	40° - 45° Dips 70° - 75° Dips	
NX Cores MW-9	Fractures	40° - 45° Dips 65° - 70° Dips 70° - 75° Dips	

(1) Ecology and Environment, Inc. (March 25, 1988).
(2) Woodward-Clyde Consultants (December 9, 1983).

strikes to the northwest with dips to the northeast. Finally, study of the NX cores indicated fracture dips of 30° to 35°, 40° to 45°, and 50° to 54° in MW-2; 40° to 45° and 70° to 75° in MW-4 and MW-9 and 65° to 70° also in MW-9. Overall there appears to be at least one set of conjugate fractures striking both northeast and northwest. The dip of these fractures is quite variable ranging from 15° to 85°. (A summary of measurements of geologic structures is given in Table 3-15.)

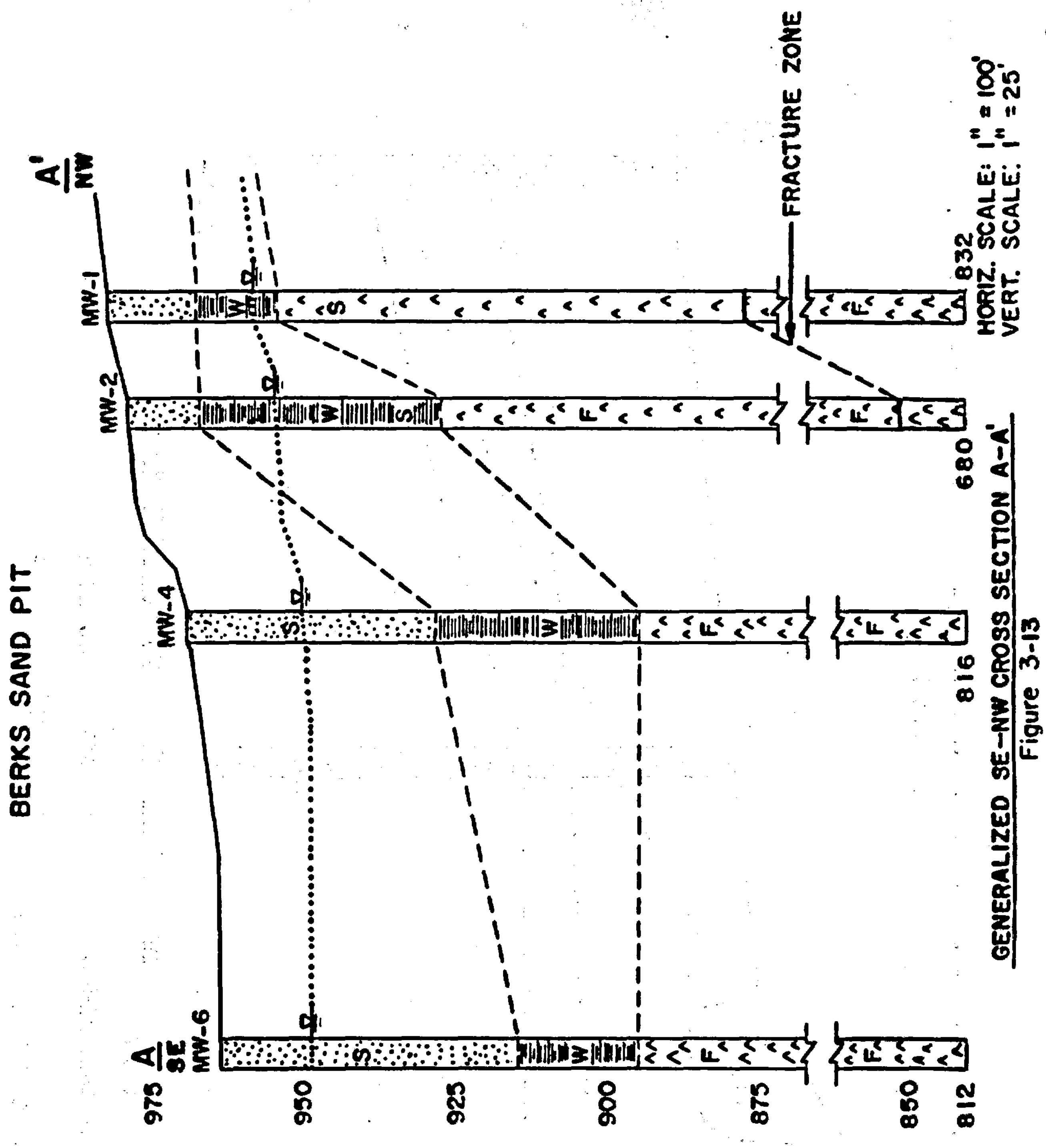
The granitic gneiss is highly weathered throughout the area and the thickness of the weathered overburden is quite variable. There is, in general, no district boundary between the overburden and the weathered bedrock. Rather, there is a gradual change from saprolite to weathered granitic gneiss to fresh granitic gneiss. Generalized cross-sections are given in Figures 3-13 and 3-14. The contact between units indicated on the cross-section are based on verbal descriptions obtained from the boring logs and are approximate.

Saprolite is a weathering product of granites and gneisses. In the vicinity of the site the saprolite consists of a light brown, tan to orange clay with some silt and sand, and quartz and feldspar fragments. The saprolite changes to clay and sand with quartz and weathered granitic gneiss fragments at depth. Some local zones in the saprolite show evidence of foliation and relict structures.

The boring logs and seismic refraction profiles show a thick saprolite development in the vicinity of MW-1, MW-2, MW-4 and MW-9. A northwest trending, deeply weathered zone also was identified in this area by the borehole imaging. This zone of increased saprolite development and bedrock weathering may be indicative of a major fracture zone in the vicinity of MW-1, MW-2, MW-4 and MW-9.

The predominant surface soils at the site, according to the U. S. Department of Agriculture Soil Survey of Berks County (10) are the Chester channery silt loam (ChB2) and the Chester very stony silt loam (CnB). These are deep, well drained soils formed from material weathered from granitic gneiss and underlain by sandy saprolite. It should be noted that the C horizon (greater than approximately 3.6 feet deep) of the Chester series has "many manganese and iron films on ped surfaces" (10). In general, surface soils are well drained and have a permeability of approximately 10 gpd/ft^2 to 30 gpd/ft^2.

BERKS SAND PIT



GENERALIZED SE–NW CROSS SECTION A–A'

Figure 3-13

SAPROLITE: SAND AND CLAY

S SATURATED ZONE

W HIGHLY WEATHERED TO WEATHERED GRANITIC GNEISS

APPROXIMATE POTENTIOMETRIC SURFACE

F WEATHERED TO FRESH GRANITIC GNEISS

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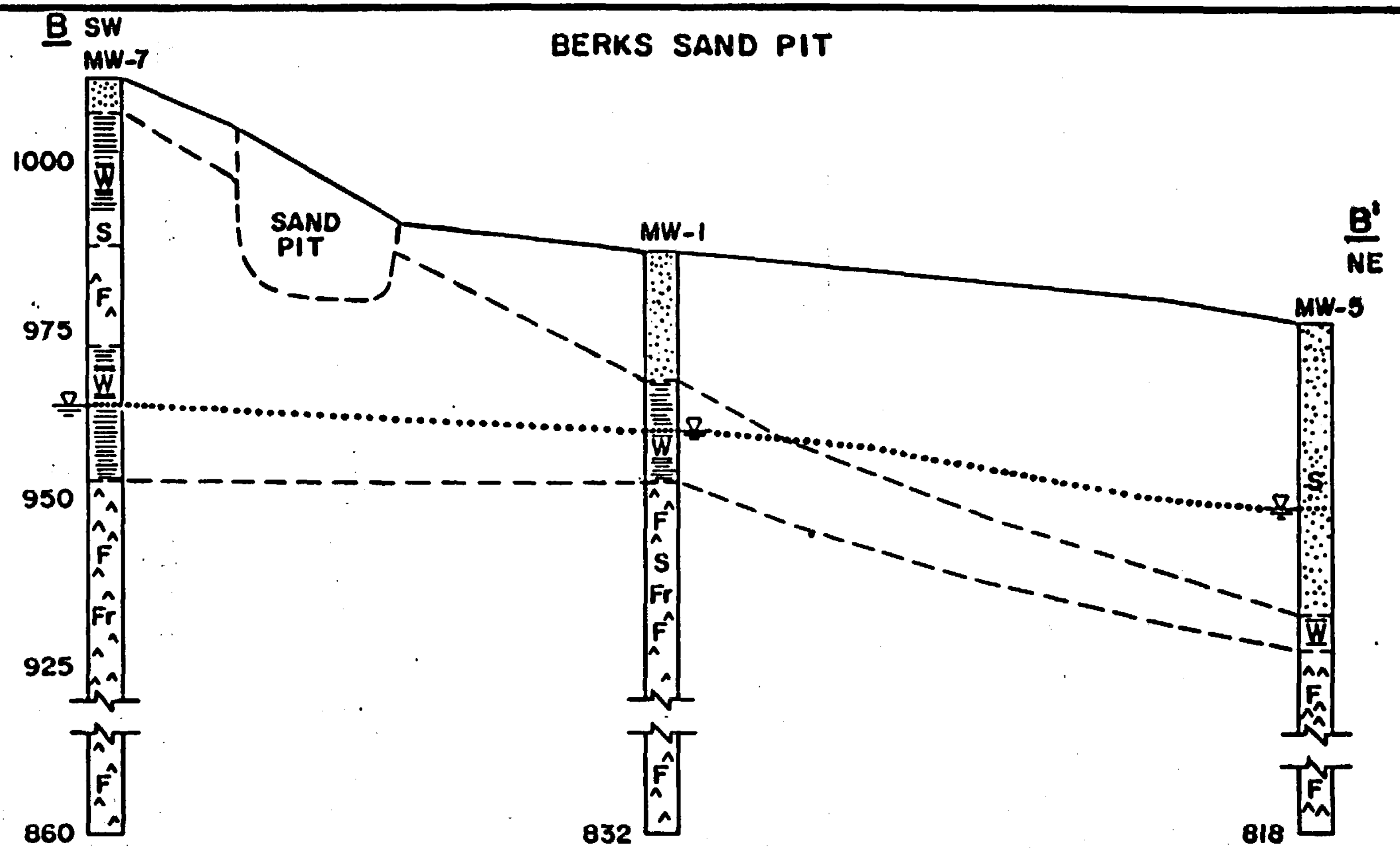
BERKS SAND PIT



GENERALIZED SW-NE CROSS SECTION B-B'

SAPROLITE: SAND AND CLAY

W HIGHLY WEATHERED TO WEATHERED GRANITIC GNEISS

APPROXIMATE POTENTIOMETRIC SURFACE

F WEATHERED TO FRESH GRANITIC GNEISS

S SATURATED ZONE

Fr MAJOR FRACTURE

HORIZ. SCALE: 1" = 100'

VERT. SCALE: 1" = 25'

Figure 3-14

Fill material consisting of medium grained sand with some clay and silt was noted on the R-3 property in the vicinity of the former sand pit. The maximum depth of this fill material is approximately 10 feet (TB-4 and TB-6).

3.8.2 Overview of Site Hydrogeology

Groundwater in the Berks Sand Pit area is encountered in both the soil overburden and in the bedrock. The bedrock, a granitic gneiss, has a low primary porosity and permeability but has a significant secondary porosity and permeability due to the presence of a complex fracture system. In general, the fractures and fractured zones provide preferred avenues for groundwater movement; more specifically, highly weathered and altered fracture zones tend to provide preferred avenues for groundwater movement. Other avenues for groundwater movement as indicated by the borehole visual and geophysical logs include faults, mineralogical changes and grain size changes.

The amount of water that moves through the bedrock depends on the hydraulic gradient and the hydraulic conductivity of the fractures and their frequency of occurrence and orientation. The hydraulic conductivity of the fractures depends on such properties as dimension, interconnectedness, filling material, etc. These properties are quite variable and as a result, a highly complex flow field has developed at the site.

In general, there are a large number of interconnected fractures oriented in both a northeasterly and northwesterly direction. From plots of the extent of contamination (Drawings 4 through 7), it can be seen that the northeasterly flow direction is dominant.

Two groundwater flow regimes have been identified at the site. A shallow flow regime occurs in the overburden and a deep flow regime occurs in the fractured bedrock. The shallow flow regime consists primarily of saprolite and highly weathered bedrock. Water in this shallow aquifer may occur as perched zones, generally above saprolitic layers, and under confined to semi-confined conditions, generally beneath saprolitic layers.

The transmissivity of the shallow aquiver was measured in SW-1, SW-3 and SW-4 during the aquiver pump tests. In general, the shallow aquifer displays moderately large average transmissivities ranging from 29,500 gpd/ft^2 in SW-4 to 75,430 gpd/ft^2 in SW-3 (see Table 3-13).

The hydraulic gradient, a measure of the potential for flow in a given direction, was estimated with the following equation:

$$I = \frac{\Delta h}{\Delta l}$$

where

I = hydraulic gradient (L/L)

Δh = change in hydraulic head over some distance l (L)

Δl = distance (L)

The hydraulic gradient of the shallow aquifer was estimated from water level measurements taken from the groundwater elevation contour map of the shallow aquifer (Drawing 2). Measurements of the change in head over distance was taken between SW-1 and SW-2, and between SW-4 and SW-5. The average hydraulic gradient was found to be 0.06 feet per foot (see Table 3-16). It also can be seen from Drawing 2 and Figure 3-15 that the direction of groundwater flow varies approximately radially about SW-4 from the south to the northwest.

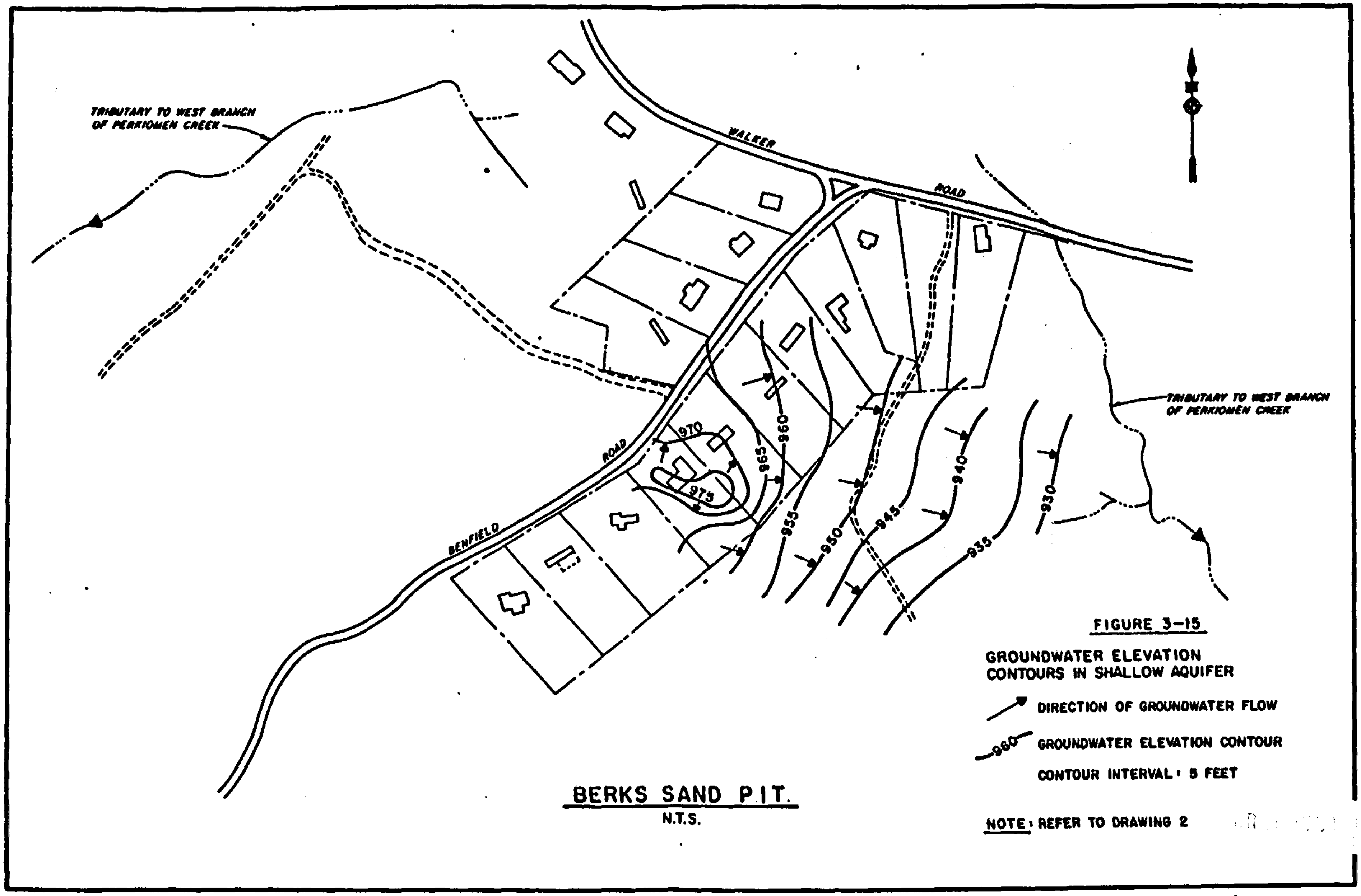
The deep flow regime consists primarily of fractured granitic gneiss. Groundwater in the fractured bedrock aquifer generally occurs under confined to semi-confined conditions in highly weathered fracture zones. The saprolite in the overburden above the bedrock may be acting as a leaky confining layer.

The transmissivity of the bedrock aquifer and of particular fractures was estimated using packer and aquifer pump tests. The packer tests were intended to measure the transmissivity (T) of individual fractures and fracture zones. T values calculated from the packer tests (Sections 3.6 and Appendix B) range from approximately 12 gpd/ft^2 in MW-7 to 26,400 gpd/ft^2 in MW-3. This wide range of T values (three orders of magnitude) gives an indication of the variable nature of fracturing. Higher transmissivity fractures are probably more weathered and altered than low transmissivity fractures. Aquifer pump tests were performed to develop averaged T values. Average transmissivities ranged from 5440 gpd/ft^2 in MW-1 to 22,310 gpd/ft^2 in MW-5. The pump tests indicate that: 1) transmissivities vary from point to point in the aquifer depending on the nature, number and weathering of the fractures that are present; 2) well yields are lower in less fractured areas or areas where the fractures are less weathered; 3) the transmissivity in the soil overlying the bedrock is up to approximately one

Table 3-16

BERKS SAND PIT
HYDRAULIC GRADIENT IN SHALLOW AQUIFER

Wells/Water Level Elevation	Distance between Wells (ft)	Hydraulic Gradient
SW-1 to SW-2 954.42 - 949.51	120	0.04
SW-4 to SW-5 978.15 - 934.70	530	0.08
	Average	0.06


TRIBUTARY TO WEST BRANCH OF PERKIOMEN CREEK
WALKER ROAD
BENFIELD ROAD
970
975
965
960
955
950
945
940
935
930
TRIBUTARY TO WEST BRANCH OF PERKIOMEN CREEK
FIGURE 3-15
GROUNDWATER ELEVATION CONTOURS IN SHALLOW AQUIFER
DIRECTION OF GROUNDWATER FLOW
960 GROUNDWATER ELEVATION CONTOUR
CONTOUR INTERVAL: 5 FEET
NOTE: REFER TO DRAWING 2
BERKS SAND P.I.T.
N.T.S.

order of magnitude larger than the transmissivity for the bedrock (5440 gpd/ft^2 in MW-1 as opposed to 75,430 gpd/ft^2 in SW-3).

Measurements of the change in hydraulic head over distance were taken from the groundwater contour map (Drawing 3) between MW-1 and MW-5 and between MW-9 and MW-4 and between MW-3 and MW-6 to estimate the hydraulic gradience (see Table 3-17). The average gradient was found to be approximately 0.03 feet per foot. As with the shallow aquifer, the flow direction in the fractured bedrock aquifer varies radially about SW-4 from the southeast to the northwest (see Figure 3-16).

The above information (the transmissivity and hydraulic gradient) is often used to estimate the quantity and velocity of water moving through an aquifer using Darcy's Equation. Darcy's Law, however, is not strictly applicable to flow in fractured porous media. Therefore, no groundwater velocity estimates were made using this relationship.

Accurate groundwater velocity estimates could not be obtained due to the highly irregularly fractured nature of the bedrock and complex groundwater flow paths. Our investigation did not uncover the existence of readily applicable groundwater models or flow equations for the conditions encountered at the site. The extent of contamination has been determined from the analytical results of samples taken during this investigation and is discussed in Section 5.0.

Table 3-17

BERKS SAND PIT
HYDRAULIC GRADIENT IN FRACTURED BEDROCK AQUIFER

Wells/Water Level Elevation	Distance between Wells (ft)	Hydraulic Gradient
MW-1 to MW-5 958.79 - 947.99	395	0.03
MW-9 to MW-4 957.08 - 951.43	155	0.04
MW-3 to MW-6 955.78 - 948.28	380	0.02
	Average	0.03

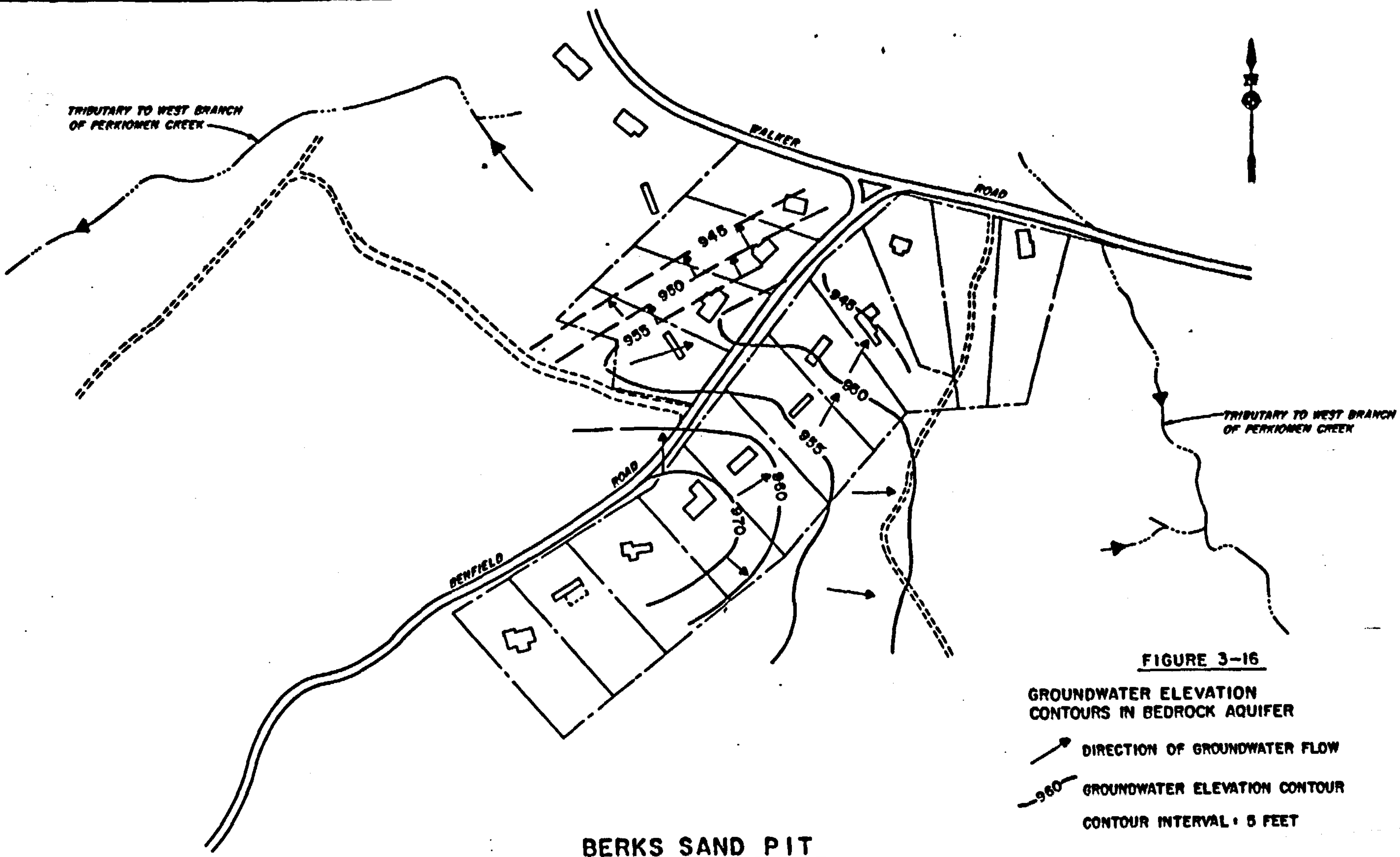


FIGURE 3-16

GROUNDWATER ELEVATION
CONTOURS IN BEDROCK AQUIFER

DIRECTION OF GROUNDWATER FLOW

960 GROUNDWATER ELEVATION CONTOUR

CONTOUR INTERVAL: 5 FEET

NOTE: REFER TO DRAWING 2

BERKS SAND PIT

N.T.S.

HAZARDOUS SUBSTANCES

4.0 HAZARDOUS SUBSTANCE INVESTIGATION

4.1 Introduction

The purpose of the hazardous substance investigation was to establish the waste types present at the Berks Sand Pit Site, and the waste component characteristics and behavior. This hazardous substance investigation was performed by taking air, soil, surface water, and groundwater samples, and analyzing those samples following Contract Laboratory Program (CLP) protocols as well as other approved EPA methods. In addition to confirming the presence of contaminating substances on site, the surface water and groundwater studies helped to determine the quantity, location, and the containment of these substances. The air study was performed to assess the potential risk associated with this route of exposure. Finally, the soil study was performed, in part, to attempt to locate the source(s) of contamination as well as evaluate the degree to which this medium contains hazardous substances.

4.2 Sampling Summary

4.2.1 Air

An air surveillance program was performed by Phoenix Safety Associates, Limited to:

- Determine the quantity of airborne contaminants at the Berks Sand Pit Site, and thus the level of protection needed to control personnel exposures;

- Document the presence of contaminants migrating from the site to residential areas as a result of investigation activities;

- Generate information from the on-site activities to indicate necessary changes in protective measures for on-site personnel or affected populations downwind from the site.

As part of this surveillance, sampling was performed to determine the levels of organic vapors and inorganic dusts as listed in NIOSH Methods 1003, 1500, 1501, and 7300 (see Table 5-1).

The sampling was performed in three rounds: The first round was performed in May 1987; The second round was performed in August and September 1987 during the drilling of MW-2, MW-3, and MW-6; The third was performed in February 1988 after site activities ceased. For the pre-activity and post-activity sampling, two air samples were drawn -- one upwind of the site and one downwind of the site. During drilling, samples were taken from the exclusion zone, in addition to the ones drawn from upwind and downwind locations. One blank sample accompanied each shipment to the laboratory.

4.2.2 Soil Atmosphere

A slam-bar soil gas survey was conducted as part of the site reconnaissance to determine the location of near-surface organic vapor anomalies. The slam-bars used for this study were constructed from 1-inch I.D. black iron pipe containing 16 1/4-inch holes drilled in the bottom six inches of the pipe. A rectangular grid consisting of 27 sampling points on approximately 200-foot centers was imposed on the site. Sampling point locations are illustrated in Plate 1. At each sampling point, a decontaminated slam-bar was driven into the soil using an 18-inch fence post driver. The slam-bars were driven until the full penetration length of 30 inches was obtained or the driving refusal limit of the pipe was met. The soil in the Berk Sand Pit study area is very rocky so the slam-bar was moved slightly at times to allow for the full penetration length of the slam-bar into the soil.

After each slam-bar was installed, the pipe was hand-vacuum pumped for five minutes. After pumping, an initial reading was taken from the slam-bar using an Organic Vapor Analyzer (OVA). Following the reading, the slam-bar was allowed to stabilize in the soil for about one hour. After this time, the final OVA reading was taken from the slam-bar. The slam-bar the was pulled from the ground and, immediately, an OVA reading was taken in the hole left by the slam-bar.

4.2.3 Soil

An extensive drilling program was conducted in the vicinity of the former sand pit from August 1987 to November 1987. Two sets of soil test borings were completed to determine the extent of near-surface soil contamination in the study area. The first set of soil borings, referred to with the TB designation, were completed between August 1987 and November 1987 on the former sand pit on the Van Elswyck, Lieppert and Leibensperger properties. The second set of soil borings, referred to with the LTB designation, was completed between

August 1987 and September 1987 on the Leibensperger property. Another test boring, BG-1, was completed near the EPA Superfund (Longswamp Township Well Association) well to provide background control. Additionally, seven shallow monitoring wells, designated as SW, and nine deep wells, designated as MW, were completed as part of the drilling program.

Selected soil samples, based on field screening, were collected from the borings and sent to the laboratory for analysis. A total of 19 soil samples were collected for the TB soil borings, based on OVA and visual screening. A total of 10 soil samples were collected at the LTB locations: five samples are composites of hand (power) auger cuttings and five samples were collected with standard split-spoons. One soil sample from the SW soil borings and 29 soil samples from the MW soil borings also were collected.

4.2.4 Surface Water and Sediments

The purpose of sampling springs, seeps, mine pools and watercourses in the project area was to identify the extent of contamination and quantify potential impacts of contamination on local surface waters. Surface water samples were collected at 13 springs, seeps, mine pools, and/or water courses. Sediment samples also were taken to give an indication of possible chronic contamination. Two rounds of water sampling and one round of sediment sampling were conducted at the 13 sampling points. The first sampling round was conducted in November 1987 and included both sediment and surface water sampling. The second sampling round was conducted in January through March 1988 and included only surface water sampling at the 13 sampling points.

All sediment samples were taken approximately 24 hours before the water samples. The reason for this was to prepare the sampling points for the water sampling. In many cases, small holes had to be dug so that water could accumulate to a sufficient depth to be sampled. The sediments were allowed to settle for approximately 24 hours before the surface water samples were taken.

4.2.5 Groundwater

Groundwater monitoring was performed during the site investigation to characterize and quantify the contamination present in this media. Three kinds of groundwater samples were collected: packer test, residential well, and monitoring well samples. The packer test samples were collected during aquifer tests run in October 1987, and their results provide a contamination versus depth relationship. Residential wells were sampled during the site reconnaissance in May 1987. All the residential wells and the monitoring wells sampled during a September 1987 sampling round and again in a January 1988 through March 1988 round. Results from the well sampling indicate the areal extent of contamination at the site.

All residential and groundwater samples for the final sampling round (January through March 1988) were collected in January and February 1988. However, the laboratory encountered equipment interference problems that voided results obtained from the EPA Analytical Method No. 601. Also, holding times were exceeded on certain samples for 624/625 analysis, and nine monitoring well samples were misplaced and, therefore, were not tested. The inorganic samples from the January 1988 and February 1988 sampling were not affected. The residential and monitoring wells were resampled and tested for these organic parameters in March 1988.

4.3 Laboratory Analysis

4.3.1 Laboratories

A summary of the laboratories used during the Remedial Investigation is provided by Table 4-1. As indicated, NUS Corporation tested the samples taken during the site reconnaissance and the air surveillance samples taken throughout the Remedial Investigation. Compuchem Laboratories performed the analytical testing of samples taken during monitoring well construction and concurrent field sampling. Zenon Environmental performed the organic (volatile, semi-volatile, and pesticide/PCB) analyses from October 1987 to March 1988. During this period, Compuchem performed the associated inorganic analyses, and both organic and inorganic analyses when problems occurred with delivery of samples in a timely fashion.

Because of the laboratory problems presented in Section 4.2, an additional round of sampling was collected in March 1988 to replace the organic samples collected during the January-February 1988 sampling round. Because a short turn-around was required and Zenon Environmental had a limited capacity, they contracted Pace Laboratory to perform the Method 601 analyses for purgeable halocarbons. Samples from the January-February sampling round that were sent to Compuchem for inorganic analyses were unaffected.

Table 4-1

SUMMARY OF LABORATORIES

Laboratory	Month/Year of Sampling					
	Air	Volatiles (624)	Semi-Volatiles (625)	Pesticide/ PCB (608)	Inorganics	Purgeables (601)
NUS	May 1987 - March 1988	May 1987	May 1987	May 1987	May 1987	May 1987
Compuchem	-	August - September 1987	August - September 1987	August - September 1987	August 1987 - February 1988	September 1987
Zenon	-	October 1987 - March 1988	October 1987 - March 1988	October 1987 - March 1988	-	October 1987
Pace	-	-	-	-	-	March 1988

4.3.2 Procedures

Table 4-2 summarizes the laboratory methods used to analyze for analytes found on the Target Analyte List (TAL). The TAL is comprised of 23 metals plus cyanide.

Table 4-3 lists and summarizes the laboratory methods used to analyze for organic compounds found at the Berks Sand Pit Site. EPA Methods 624, 625 and 608 are used to analyze for compounds found on the Target Compound List (TCL).

Method 601 was performed to analyze for eight key volatile organics. These compounds are also found on the TCL. However, Method 601 provides lower detection limits for these eight compounds than Method 624. For site reconnaissance, the samples were analyzed for the TAL and the TCL. Starting in August 1987, Method 601 was used in addition to the TAL and TCL for groundwater samples to provide a lower detection limit.

4.4 Data Validation

Data validation was performed for the analytical results of the volatile, semi-volatile, pesticide/PCB, and inorganic analyses. The laboratories performing these and other analyses are listed in Table 4-1. This evaluation was performed by Baker/TSA and Free-Col Laboratories according to laboratory data validation functional guidelines as outlined by the USEPA office of Emergency and Remedial Response and as modified by the current Contract Laboratory Program Statements of Work. The air and purgeable (EPA Method 601) results were not validated because these analyses are not included in the Contract Laboratory Program (CLP) protocols.

The analytical results in the database, as a result of laboratory reports and the data validation, were flagged with the following letters:

B - Material detected in laboratory blank. The associated numerical value is the quality detected in the sample.

U - The material was analyzed for, but was not detected. The associated numerical value is the estimated sample quantitation limit.

Table 4-2

INORGANIC LABORATORY TESTING METHODS

Description	Analyte (s)	Method Number
Atomic Absorption Methods Flame Technique	Calcium Magnesium Potassium Sodium	215.1 CLP-M* 242.1 CLP-M 258.1 CLP-M 273.1 CPL-M
Mercury Analysis in Water by Manual Cold Vapor Technique	Mercury	245.1 CLP-M
Mercury Analysis in Water by Automated Cold Vapor Technique	Mercury	245.2 CLP-M
Mercury Analysis in Soil/Sediment by Manual Cold Vapor Technique	Mercury	245.5 CLP-M
Method for Total Cyanide Analysis in Water	Cyanide	335.2 CLP-M
Method for Total Cyanide Analysis in Soil/Sediment	Cyanide	335.2 CLP-M
Inductively Coupled Plasma - Atomic Emission Spectrometric Method	Aluminum, Antimony, Arsenic, Barium, Beryllium, Boron, Cadmium, Calcium, Chromium, Cobalt, Copper, Iron, Lead, Magnesium, Manganese, Molybdenum, Nickel, Potassium, Selenium, Silica, Silver, Sodium, Thallium, Vanadium, Zinc	200.7 CLP-M
Atomic Absorption Methods Furnace Technique	Antimony Arsenic Beryllium Cadmium Chromium Lead Selenium Silver Thallium	204.2 CLP-M 206.2 CLP-M 210.2 CLP-M 213.2 CLP-M 218.2 CLP-M 239.2 CLP-M 270.2 CLP-M 272.2 CLP-M 279.2 CLP-M

*CLP-M Modified for the Contract Laboratory Program.

Table 4-3

ORGANIC LABORATORY TESTING METHODS

Description	Fraction	EPA Method Number
Purge and Trap Gas Chromato - graphic method	Purgeable Halocarbons	601
Gas Chromatographic (GC) Method	Organochlorine Pesticides/PCBs	608
Purge and Trap Gas Chromato - graphic/Mass Spectrometry (GC/MS)	Purgeables	624
Gas Chromatographic/Mass Spectrometry (GC/MS) Method	Base/Neutrals and Acids	625

J - The associated numerical value is an estimated quantity because quality control criteria were not met.

R - Quality Control indicates that data are unusable (compound may or may not be present). Resampling and re-analysis is necessary for verification.

N - Presumptive evidence of presence of material (tentative identification).

Only those results not flagged and those flagged only with a "B" were considered as positive hits in the database. Similarly, results flagged with an "UJ" or "BUJ" were made equal to zero in the database. Any results flagged with "J," "R," or "N" were deleted from the database and are noted with an asterisk in the data summary in Appendix E.

The database created for the public health evaluation contains analytical results for 22 volatile organic compounds, 20 semi-volatile compounds, and 24 inorganic parameters (23 metals and cyanide). As a result of the data validation, 26 percent of the results were discarded and not used in the database. Of the discarded data, 57 percent is positive hit data (results greater than the detection limit).

Broken down by analytical group, 22 percent of the volatile compound results, 17 percent of the semi-volatile compound results, and 28 percent of the inorganic parameter results were discarded from the database. For both volatile and semi-volatile compounds, 41 percent of the discarded results were positive hit data. For the inorganic parameters, 80 percent of the discarded data was positive hit data. There appears to be no large bias toward discarding positive hit data compared to discarding results reported at the detection limit.

The data validation results' effect on the database by media are as follows:

- Thirty-two percent of the residential well results were discarded, with 53 percent of the rejected results being positive hit data;

- Thirty-five percent of the surface water results were discarded, with 60 percent of the rejected results being positive hit data;

- Thirty-four percent of the sediment results were discarded, with 48 percent of the rejected results being positive hit data; and

- Fourteen percent of the soil results were discarded with 61 percent of the rejected results being positive hit data.

Additionally, the results of 19 samples taken during the packer tests in October 1987 were wholly rejected. Of the remaining monitoring well samples, 33 percent were discarded, with 58 percent of the rejected results being positive hit data.

A large impact of the data validation on the data is that the results from the packer test samples collected in October 1987 were flagged as unusable (R). Specifically, the GC/MS tuning and mass calibration criteria for these analyses were not met. Although the results are unusable according to the guidelines, the validating laboratory noted in their worksheets, that they may be used with appropriate discretion. These data are not used in the public health evaluation presented in Section 6.0. They are used in Section 5.0, Nature and Extent of Contamination, to qualitatively identify the direction and progress of the plume.

4.5 Waste Component Characteristics and Behavior

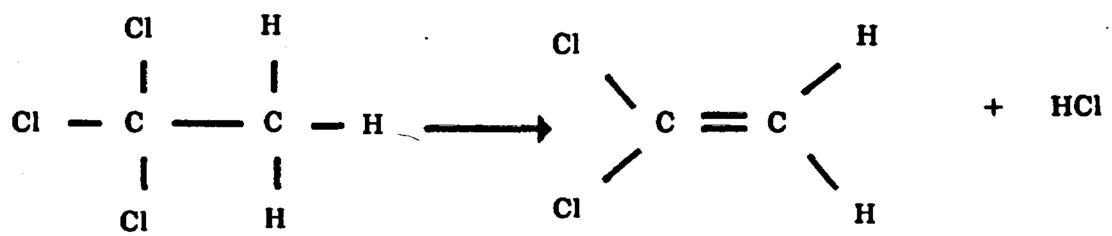
A total of 45 chemicals were identified at the Berks Sand Pit Site including 15 volatile organic compounds (VOCs), 10 semi-volatile organic compounds (SVOCs), and 20 metals (M). Groundwater (monitoring wells and residential wells) contained a total of 25 chemicals (seven VOCs, three SVOCs, and 15 Ms); surface water (seeps, springs, and creek samples) contained a total of 27 chemicals (seven VOCs, three SVOCs, and 17 Ms); and, soil/sediment (monitoring well cuttings, test borings, and surface water sediments) contained a total of 30 chemicals (four VOCs, six SVOCs, and 20 Ms.) The five indicator compounds selected are chlorinated hydrocarbons: 1,1,1-trichloroethane, 1,2-dichloroethene (cis and trans), 1,1-dichloroethane, tetrachloroethene, and 1,1-dichloroethane. An explanation of the selection process is described in Section 6.1.3, Selection of Indicator Chemicals. The physical properties of water solubility, vapor pressure, log octanol-water partition coefficient, Henry's Law constant, and soil organic carbon partition coefficients are presented in Table 6-5 for these compounds. Also, the mobility and persistence of these compounds, with relation to biotic and abiotic degradation as well as physical properties, are discussed in Section 6.2.2, Toxicity and Environmental Profiles.

Chlorinated hydrocarbons have numerous commercial uses, such as intermediates for the production of polymers and fluorohydrocarbons, chemical products, and solvents. The two largest applications of chlorinated solvents are metal cleaning and the use of tetrachloroethane in the dry cleaning industry.

For a given hydrocarbon molecule, increased chlorination results an increase in non-flammability, density, and viscosity; it also provides for better solubility in a large number of inorganic and organic substances. Along with an increasing chlorine content, there is an exhibit decrease in specific heat, electric constant and solubility in water.

All volatile organic solvents are, to some degree toxic. However, the toxicity of a solvent cannot be determined by its degree of chlorination or the molecular structure of that solvent. For example, 1,1,1-trichloroethane is among the least toxic metal-cleaning solvents, and has a MCL of 200 µg/l. Its isomer, 1,1,2-trichloroethane, is one of the most toxic chlorinated solvents with a MCL of 10.

Chlorinated alkanes in water can produce alkenes through elimination reactions. The following formula is a dehydrohalogenation reaction that transforms 1,1,1-trichloroethane to 1,1-dichloroethene under abiotic conditions.



1,1,1 - trichloroethane 1,1 - dichloroethene hydrochloric acid

Because of the presence of both 1,1,1-trichloroethane and 1,1-dichloroethene at the site, this reaction may partially or fully account for the presence of 1,1-dichloroethene at the site. This mechanism also is important from a risk assessment standpoint, because 1,1-dichloroethene has a MCL of only 7 µg/l.

EXTENT OF CONTAMINATION

5.0 NATURE AND EXTENT OF CONTAMINATION

This chapter describes the nature and extent of contamination at the Berks Sand Pit Site. The types of contaminants and their distribution in the air, soil atmosphere, soil, surface sediment, surface water and groundwater are discussed. A total of 40 chemicals (see Table 5-1) were detected at the site and screened according to the guidelines given in the Superfund Public Health Evaluation Manual (14).

The result of this screening process is a list of four volatile organic compounds that pose a risk to human health and/or the environment. Section 6.0 of the Remedial Investigation (RI) provides a detailed description of this screening process.

The four constituents that were identified as indicator parameters in Section 6.0 are:

- 1,1-dichloroethene
- 1,1-dichloroethane
- 1,1,1-trichloroethane
- Tetrachloroethene

The following sections describe the extent of these contaminants in the various media at the Berks Sand Pit Site.

5.1 Air

An air surveillance program was performed by Phoenix Safety Associates, Limited to:

- Determine the quantity of airborne contaminants at the Berks Sand Pit Site, and thus the level of protection needed to control personnel exposures;

- Document the presence of contaminants migrating from the site to residential areas as a result of investigation activities;

- Generate information from the on-site activities to indicate necessary changes in protective measures for on-site personnel or affected populations downwind from the site.

Table 5-1

CONSTITUENTS DETECTED AT THE BERKS SAND PIT SITE

Volatile Organic Compounds

Methylene Chloride	1,1,1-trichloroethane*
Acetone	Benzene
1,1-dichloroethene*	Tetrachloroethene*
1,1-dichloroethane*	Toluene
Xylene (total)	
2-Butanone	

Semi-Volatile Organic Compounds

1,4-dichlorobenzene	Di-n-octylphthalate
Di-n-butylphthalate	Benzo(b)fluoranthene
bis(2-ethylhexyl)phthalate	Benzo(k)fluoranthene
4-methylphenol	N-nitrosodiphenylamine (1)
Fluoranthene	Benzo(a)pyrene

Inorganics

Aluminum	Cyanide
Barium	Magnesium
Beryllium	Manganese
Cadmium	Mercury
Calcium	Nickel
Chromium	Potassium
Cobalt	Selenium
Copper	Sodium
Iron	Vanadium
Lead	Zinc

*Indicator parameters; see Section 6.0 for details.

As part of this surveillance, sampling was performed to determine the levels of organic vapors and inorganic dusts as listed in NIOSH Methods 1003, 1500, 1501, and 7300 (see Table 5-2).

The sampling was performed in three rounds: The first round was performed in May 1987, before site activities commenced. The second round was performed in August and September 1987 during the drilling of monitoring wells MW-2, MW-3, and MW-6. The third was performed in February 1988 after site activities ceased.

For the pre-activity and post-activity sampling, two air samples were drawn -- one upwind of the site and one downwind at the site. During drilling, samples were taken from the exclusion zone, as well as from upwind and downwind locations. One blank sample accompanied each shipment to the laboratory.

The contaminants of concern during the course of the surveillance were chlorinated, volatile hydrocarbons, particularly 1,1-dichloroethene, 1,2-dichloroethene and 1,1,1-trichloroethane. No organic compounds, including the contaminants of concern or the four indicator parameters, were detected in samples analyzed using Methods 1003, 1500, or 1501. Metal analytes were tested for using Method 7300. At least one metal listed in Table 5-2 was detected in each inorganic sample or blank submitted. The calculated air concentrations are shown in Table 5-3. Although these metals were detected, all were at levels well below the threshold limit values as provided in Table 5-3. The sample concentrations do not vary regularly in relation to the sampling location or activity during sampling, and do not vary greatly from the concentrations found in the blanks. It can be concluded that the concentration found in the samples are attributable to both laboratory contamination and contamination introduced during shipment.

5.2 Soil Atmosphere

The soil atmosphere at the Berks Sand Pit Site was screened for volatile organic compounds with an OVA. Measurements of the concentration of volatile organic compounds in the soil atmosphere were taken at slam-bar/OVA soil gas survey sampling points (see Figures 3-2 and Figure 3-3), and at the TB and LTB soil boring locations (see Figure 3-7). Although elevated levels of volatile organic compounds were found in the soil atmosphere, no soil contamination or other source for the elevated readings was noted.

Table 5-2

LABORATORY METHODS USED FOR AIR SAMPLES

Method 1003 - Hydrocarbons, Halogenated I

1,1,1-trichloroethane
1,1-dichloroethylene
1,2-dichloroethane

Method 1500 - Hydrocarbons, BP 36-126°C

Benzene
Toluene
Hexane
Cyclohexane
Cyclohexene
n-Heptane
Methylcyclohexane
n-Octane
n-Pentane

Method 1501 - Hydrocarbons, Aromatic

Benzene
Toluene
Xylenes
Ethylbenzene
Cumene
Styrene
Naphthalene
p-tert - Butyltoluene
d-Methylstyrene
Vinyltoluene

Method 7300 - Elements (ICP)

Arsenic
Barium
Cadmium
Chromium
Lead
Mercury
Selenium
Silver

Table 5-3

AIR CONCENTRATIONS OF INORGANIC PARAMETERS

	Upwind µg/m³	Downwind µg/m³	Blank (1)	TWA (2)
Date	5/29/87	5/29/87	--	--
Arsenic	ND	ND	ND	200
Barium	1.5	ND	3.5	500
Cadmium	0.10	0.33	0.60	50
Chromium	0.83	1.04	1.25	500
Lead	6.0	7.1	4.8	150
Mercury	0.083	0.083	0.083	50
Selenium	ND	ND	ND	200
Silver	ND	ND	ND	100

(1) No air was drawn through the blank equivalent air concentration based on a sampling time of 480 minutes and an air flow rate of 2 liters per minute.

(2) Threshold Limit Value - Time Weighted Average.

ND - Not detected.

Table 5-3

AIR CONCENTRATIONS OF INORGANIC PARAMETERS (Continued)

	Exclusion Zone MW-2	Downwind MW-2	Blank MW-2 (1)	Downwind MW-2	TWA
Date	9/10/87	9/10/87	--	9/14/87	--
Arsenic	ND	ND	ND	0	200
Barium	6.3	0.83	0.21	0	500
Cadmium	0.020	0.020	0.083	0	50
Chromium	2.7	2.0	1.3	10.4	500
Lead	0.21	0.42	0.63	0	150
Mercury	ND	ND	0.88	0	50
Selenium	ND	ND	ND	0	200
Silver	ND	ND	ND	0	100

(1) No air was drawn through the blank equivalent air concentration based on a sampling time of 480 minutes and an air flow rate of 2 liters per minute.

ND - Not detected.

Table 5-3

AIR CONCENTRATIONS OF INORGANIC PARAMETERS (Continued)

	Upwind MW-2	Upwind MW-2 (3)	Downwind MW-6	Upwind MW-6	Downwind MW-3	Upwind MW-3	Blank (1)	TWA (2)
Date	9/11/87	9/11/87	9/11/87	9/11/87	9/11/87	9/11/87	--	--
Arsenic	ND	ND	ND	ND	ND	ND	ND	200
Barium	6.3	1.3	0.42	0.21	0.21	0.42	0.21	500
Cadmium	0.020	0.062	0.0080	0.0080	ND	0.016	0.083	50
Chromium	2.7	20	1.6	1.3	1.6	1.5	2.3	500
Lead	0.21	4.0	0.42	0.42	0.63	0.42	0.23	150
Mercury	ND	ND	ND	ND	ND	ND	ND	50
Selenium	ND	ND	ND	ND	ND	ND	ND	200
Silver	ND	0.017	ND	ND	0.0080	ND	ND	100

(1) No air was drawn through the blank. Equivalent air concentration based on a sampling time of 480 minutes and an air flow rate of 2 liters per minute.

(2) Threshold Limit Value - Time Weighted Average.

(3) No air was drawn through the blank. Equivalent air concentration based on a sampling time of 140 minutes and an air flow rate of 2.0 liters per minute.

ND - Not detected.

Table 5-3

AIR CONCENTRATIONS OF INORGANIC PARAMETERS (Continued)

	Upwind µg/m³	Downwind µg/m³	Blank (3)	TWA (2)
Date	2/25/88	2/25/88	--	--
Arsenic	ND	ND	ND	200
Barium	ND	ND	0.7	500
Cadmium	ND	ND	ND	50
Chromium	1.1	1.0	1.0	500
Lead	0.3	1.0	ND	150
Mercury	ND	ND	ND	50
Selenium	ND	ND	ND	200
Silver	ND	ND	ND	100

(2) Threshold Limit Value - Time Weighted Average.

(3) No air was drawn through the blank. Equivalent air concentration based on a sampling time of 140 minutes and an air flow rate of 2.0 liters per minute.

ND - Not detected

5.2.1 Soil Gas Survey

A slam-bar/OVA soil gas survey was conducted to evaluate the soil atmosphere. The survey was designed to locate near-surface organic vapor anomalies. The slam bar survey is discussed in detail in Section 3.3 with survey sampling points and OVA readings given in Figures 3-2 and 3-3.

Eight sampling points from the slam-bar survey showed OVA readings elevated above background: SB-1, SB-10, SB-17, SB-21, SB-21-A SB-21-B, SB-21-C and SB-21-G. The magnitude of all readings above background was less than 2 ppm except in SB-21 and SB-21-G. The readings for SB-21 and SB-21-G were 2.5 ppm and 10 ppm, respectively (see Figure 3-3).

These readings indicate the presence of an isolated soil gas "hot spot" in the vicinity of SB-21 on the R-2 property. This "hot spot" was further investigated with the TB and LTB soil borings.

5.2.2 Soil Borings

Downhole, soil, and breathing zone OVA readings were taken at the TB and LTB soil boring locations during the drilling of the borings as discussed in detail in Section 3.5. These borings were placed to investigate the soils and soil atmosphere at the slam-bar "hot spot" on the R-2 property and in the vicinity of the former sand pit on the R-3 property. The results of the downhole OVA readings for the soil borings are given in Table 3-5 (for the TB borings) and Table 3-6 (for the LTB borings).

The maximum soil gas OVA readings were detected in LTB-4 and TB-7, both 200 ppm to 300 ppm. LTB-4 is located on the R-2 property and TB-7 is located on the R-3 property. Breathing zone OVA readings for these holes were less than the 3 ppm action level but LTB-4 was completed with modified level C personal protection. It should be noted that soil samples taken from the TB and LTB locations and submitted for laboratory analyses showed no detectable levels of the four indicator parameters. No source for the elevated soil gas readings was determined and no soil contamination was noted.

5.3 Soil

Soil samples were taken during the drilling program from the TB, BG and LTB borings and from the MW and SW borings. None of the four indicator parameters identified in Section 6.0 were detected in the soils at the Berks Sand Pit Site; the maximum depth of soil sampling was less than 20 feet. Sampling location are shown in Figures 3-5 and 3-7; complete analytical results are given in Appendix E (Table E-1).

In summary, no significant contamination was detected in the soils at the site, nor was a source of the elevated soil atmosphere OVA readings identified.

5.4 Surface Sediments

Surface sediments were collected during November 1987. The sediments were collected to determine the possibility of chronic surface water contamination. Ten of 28 samples collected showed some type of volatile or semi-volatile compound. However, only one sediment sample, SP-2 displayed elevated levels of one of the four indicator parameters. The location of the surface sediment sampling points is given in Figure 3-2 and Drawing 1; analytical results are given in Appendix E (Table E-2).

One sediment sample, SP-2 showed detectable levels of 1,1-dichloroethane; 240 µg/l. The occurrence of this compound in SP-2 indicates the possibility of chronic contamination of the seeps east of the former sand pit. The source of this contamination may be the accumulation of contaminants from the groundwater over a moderately long period of time (months to years). It should be noted that 1,1-dichloroethane is a possible degradation product of 1,1,1-trichloroethane.

5.5 Surface Water

Surface water samples were collected at 12 sampling points in November 1987 and at 13 sampling points March 1988. The locations of these sampling points are given in Figure 3-2 and Drawing 1. For both rounds, three of the four indicator parameters were detected: 1,1-dichloroethane, 1,1-dichloroethene, and 1,1,1-trichloroethane. Some elevated metals also were encountered in SP-2 and SP-5.

Twelve surface water samples were collected during the first sampling round in November 1987. Of these 12 samples three, SP-3, SP-4 and SP-7, had detectable levels of two of the four indicator parameters (see Table 5-4 and Appendix E, Table E-5): 1,1-dichloroethene and 1,1,1-trichloroethane. At least one of the four indicator parameters was detected in all of the other surface water samples except SP-12. However, the analytical results for these samples did not pass the QA/QC procedures (SP-13 was not sampled because it was frozen). Surface water sampling point SP-5 also had lead detected at 62 µg/l. This is above the national primary drinking water standards (NPDWS) for lead of 50 µg/l.

Thirteen surface water samples were collected during the second sampling round in January 1988 through March 1988. Of these 13 samples, detectable levels of at least one of the four indicator parameters were found in each of nine surface water samples: SP-1 through SP-8 and SP-11. Analytical results for samples SP-1 through SP-5 and SP-11 are given in Table 5-5. It can be seen from this table that all six surface water samples show 1,1-dichloroethene concentrations above the MCL of 7 µg/l. Five of the six samples, SP-1 through SP-5 have 1,1,1-trichloroethane concentrations above the MCL of 200 µg/l. Table 5-6 shows that SP-2 also had levels of barium, cadmium and chromium above the NPDWS.

The results of these analyses indicate that some contamination by 1,1-dichloroethene, 1,1-dichloroethane and 1,1,1-trichloroethane occurs in all of the surface water samples except SP-12 and SP-13. The highest levels of contamination are in the seeps east of the former sand pit (see Figure 3-2 or Drawing 1). This contamination is probably the result of the discharge of contaminated groundwater to surface waters. The downstream extent of the surface water contamination by volatile organic compounds has not been determined. Further sampling of the surface waters may be necessary to delineate this. The detection of the elevated metals in SP-2 and SP-5 appears to be an isolated occurrence ; the source of these metals has not been determined.

All analytical results for the samples taken southwest to north of the site (SP-9 through SP-13) showed either no detectable levels of the indicator parameters or levels below the MCLs. The one exception was the detection of 1,1-dichloroethene in SP-11 (January 1988 to March 1988). Further sampling should be performed to identify any possible trends for increasing contamination in this area.

In summary, the surface waters northeast of the former sand pit exhibit the most significant contamination. The presence of volatile organic compounds (VOCs) in site surface waters is

Table 5-4

SUMMARY OF ANALYTICAL RESULTS FOR SURFACE WATER SAMPLES TAKEN IN NOVEMBER 1987

Chemical	SP-3	SP-4	SP-7
1,1-dichloroethene	19.00	38.00	17.00
1,1-dichloroethane	*	*	*
1,1,1-trichloroethane	64.00	120.00	62.00
Tetrachloroethene	ND	ND	ND

ND - Not detected.

*Data did not pass QA/QC procedures.

All units in µg/l.

Note: All other surface water samples taken in November 1987 showed detectable levels of at least one of the four indicator parameters. However, the analytical results for these samples did not pass the QA/QC procedures. SP-13 was not sampled because it was frozen.

Table 5-5

SUMMARY OF ANALYTICAL RESULTS FOR SURFACE WATER SAMPLES TAKEN IN JANUARY TO MARCH 1988

Chemical	SP-1	SP-2	SP-3	SP-4	SP-5	SP-11
1,1-dichloroethene	990.00	84.00	41.00	66.00	ND	20.00
1,1-dichloroethane	ND	ND	ND	ND	9.30	ND
1,1,1-trichloroethane	2,600.00	260.00	330.00	240.00	490.00	*
Tetrachloroethene	*	ND	ND	ND	ND	ND

ND - Not detected.

*Data did not pass QA/QC procedures.

All units in µg/l.

Note: SP-1 through SP-8 and SP-11 all showed detectable levels of at least one of the four indicator parameters. The analytical results not presented in this table did not pass the QA/QC procedures.

A

Table 5-6

SUMMARY OF METALS DETECTED IN SP-2 FOR JANUARY THROUGH MARCH 1988 SAMPLING ROUND THAT EXCEED THE NPDWS

Metal	Detected Concentration (µg/l)	NPDWS (µg/l)
Barium	3,360.00	1,000.00
Cadmium	48.00	10.00
Chromium	130.00	50.00

believed to be related to localized discharge of contaminated shallow groundwater. The metals are thought to be derived from scattered surface dumping of scrap metals which is prevalent in this area. The surface water west and northwest of the site show very low levels of VOCs.

5.6 Groundwater

Groundwater samples were collected from May 1987 to March 1988. These samples can be divided into three categories: residential well samples, monitoring well samples and packer test samples. The residential wells were sampled twice: May 1987 and January 1988 through March 1988. The monitoring wells also were sampled in two rounds: November 1987 and January 1988 through March 1988. The packer test samples were taken in October 1987.

Thirty-eight constituents were detected in the groundwater: eight VOCs, six semi-volatile compounds (SVOCs) and 14 inorganics. Only the extent of the four primary indicator chemicals, 1,1,1-trichloroethane, 1,1-dichloroethane, 1,1-dichloroethene, and tetrachloroethene will be discussed in detail since they exhibit the greatest risk to the community and the environment. No metals were detected above the NPDWS in the groundwater.

5.6.1 Residential Well Samples

Two rounds of water samples were taken from the residential wells in May 1987 and in January 1988 through March 1988. Eleven residential wells were sampled during the first sampling round (May 1987). Of these 11, five had detectable levels of at least one of the four indicator parameters as shown in Table 5-7. Only RW-4 was above the MCLs established by EPA for drinking water for both 1,1,1-trichloroethane and 1,1-dichloroethene.

Nineteen residential wells were sampled during the second round (January to March 1988). Of these 19, six had detectable levels of at least one of the four indicator parameters as shown in Table 5-8. RW-2 exceeded the MCL for 1,1-dichloroethene and RW-3 exceeded the MCL for 1,1,1-trichloroethane. Five additional residential wells (RW-4, RW-5, RW-7, RW-9 and RW-10) showed detectable levels of at least one of the indicator parameters. However, data for these wells did not pass QA/QC procedures.

Table 5-7

SUMMARY OF ANALYTICAL RESULTS FOR RESIDENTIAL WELL SAMPLES TAKEN MAY 1987

Chemical	RW-4	RW-6	RW-7	RW-10	RW-11
1,1-dichloroethene	540.00	ND	ND	ND	ND
1,1-dichloroethane	ND	ND	ND	ND	ND
1,1,1-trichloroethane	6,800.00	13.00	21.00	12.00	27.00
Tetrachloroethene	ND	ND	ND	ND	ND

ND - Not detected.

All units in μg/l.

Table 5-8

SUMMARY OF ANALYTICAL RESULTS FOR RESIDENTIAL WELL SAMPLES TAKEN JANUARY 1988 THROUGH MARCH 1988

Chemical	RW-2	RW-3	RW-6	RW-8	RW-11	RW-12
1,1-dichloroethene	8.70	ND	*	ND	*	ND
1,1-dichloroethane	ND	ND	ND	ND	ND	ND
1,1,1-trichloroethane	47.00	1,400.00	16.00	6.50	21.00	6.10
Tetrachloroethene	*	ND	ND	ND	ND	ND

ND - Not detected.

*Data did not pass QA/QC procedures.

All units in μg/l.

Figures 5-1 through 5-8 illustrate the change in 1,1,1-trichloroethane concentration over time for selected residential wells. The following observations were made:

- There appears to be large fluctuations in the concentration of 1,1,1-trichloroethane at a particular well over short periods of time. This is best illustrated by the 1983 data for RW-2, ERT-1 and ERT-2 (Figures 5-1, 5-9 and 5-10, respectively)

- The overall amount of 1,1,1-trichloroethane detected in these wells appears to be decreasing. In other words the maximum concentrations encountered in 1987 and 1988 are less than those encountered in 1983. This is best illustrated by comparing the maximum concentration of 1,1,1-trichloroethane detected at the site during the RI with the maximum 1,1,1-trichloroethane concentrations encountered historically. The maximum concentration of 1,1,1-trichloroethane detected during the RI was 7,300 µg/l in MW-4 (1988). This is significantly less than the maximum 1,1,1-trichloroethane concentrations detected at the site in 1982 and 1983: 56,000 µg/l in RW-2, 124,592 µg/l in RW-3 and 150,000 µg/l in ERT-3.

- RW-2 and RW-3 display decreasing 1,1,1-trichloroethane concentrations over time, while some wells downgradient of the former sand pit RW-6, RW-7 and RW-11 exhibit slight increases in 1,1,1-trichloroethane concentrations over time.

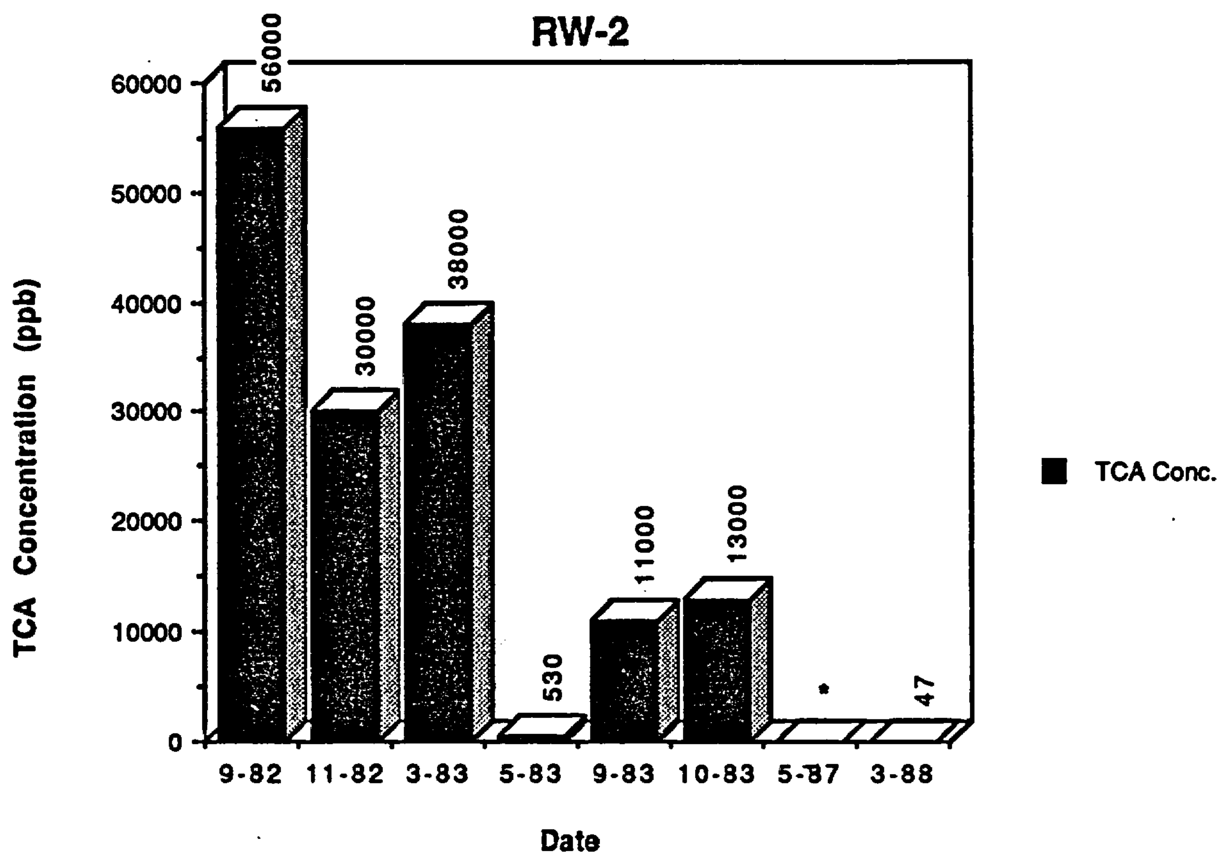
These observations indicate that the 1,1,1-trichloroethane contamination is migrating to the east and northeast and is becoming dispersed and less concentrated as it moves.

5.6.2 Monitoring Wells

The ERT wells were sampled in May 1987 and again in January 1988 through March 1988. The MW wells were sampled in November 1987 and again in February 1988 through March 1988. The SW wells were sampled in February 1988 through March 1988.

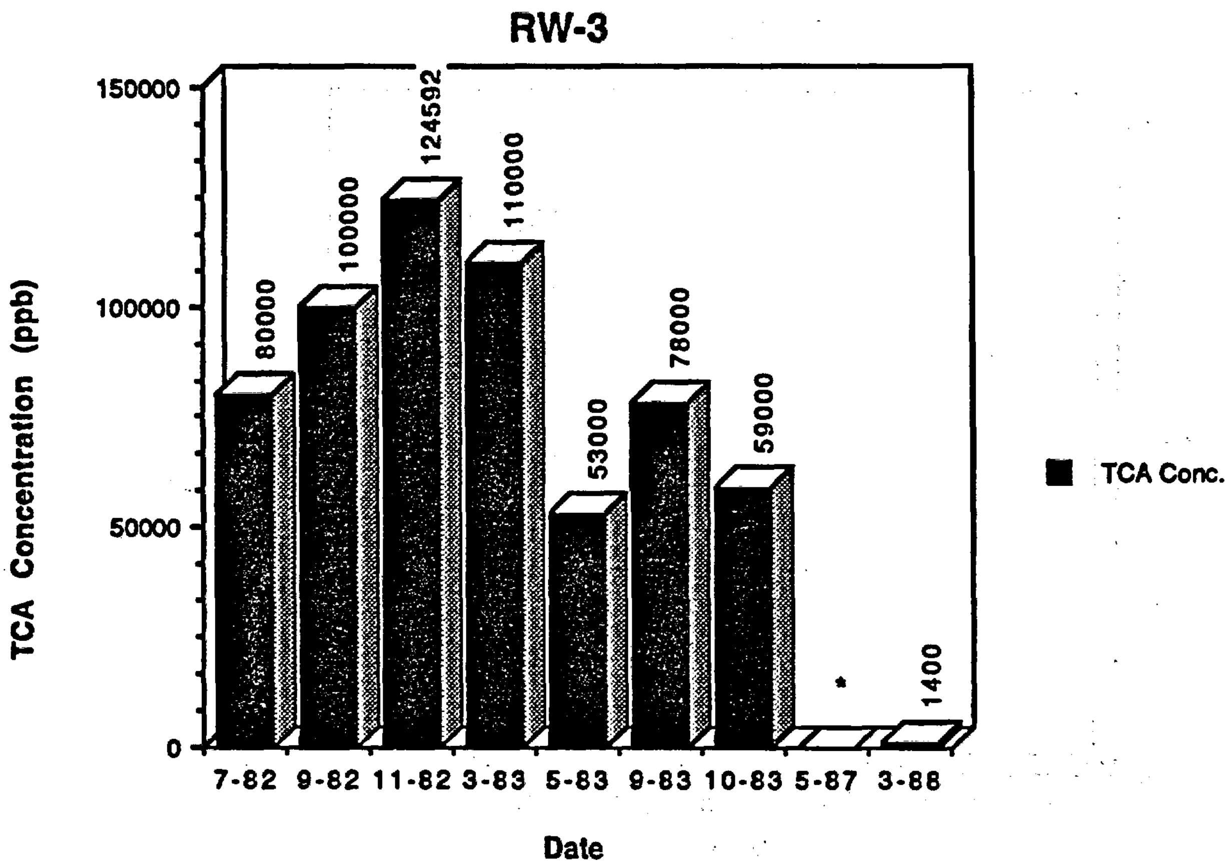
For the May 1987 sampling of the ERT wells, all three wells had detectable levels of 1,1,1-trichloroethane: 19 ppb, 5 ppb and 2,900 ppb in ERT-1, ERT-2 and ERT-3, respectively as shown in Table 5-9. 1,1,1-Trichloroethane also was detected in ERT-1, ERT-2 and ERT-3 at concentrations of 98 µg/l, 26 µg/l and 98 µg/l, respectively for the January through March 1988 sampling round. Water samples from ERT-1 and ERT-3 (1988 sampling round) also contained 1,1-dichloroethene (both at 250 µg/l) and tetrachloroethene was detected in ERT-3

Figure 5-1



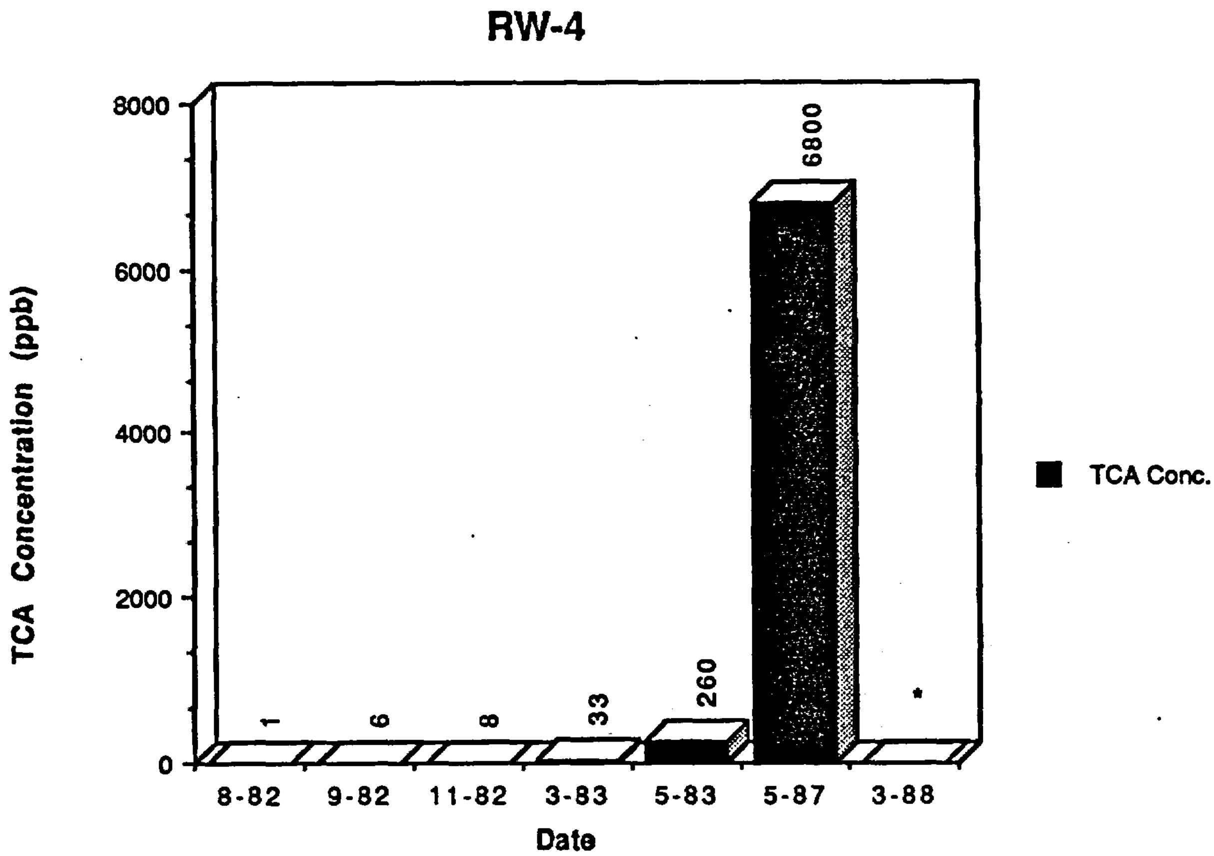
* data for 5-87 did not pass QA/QC procedures

Figure 5-2



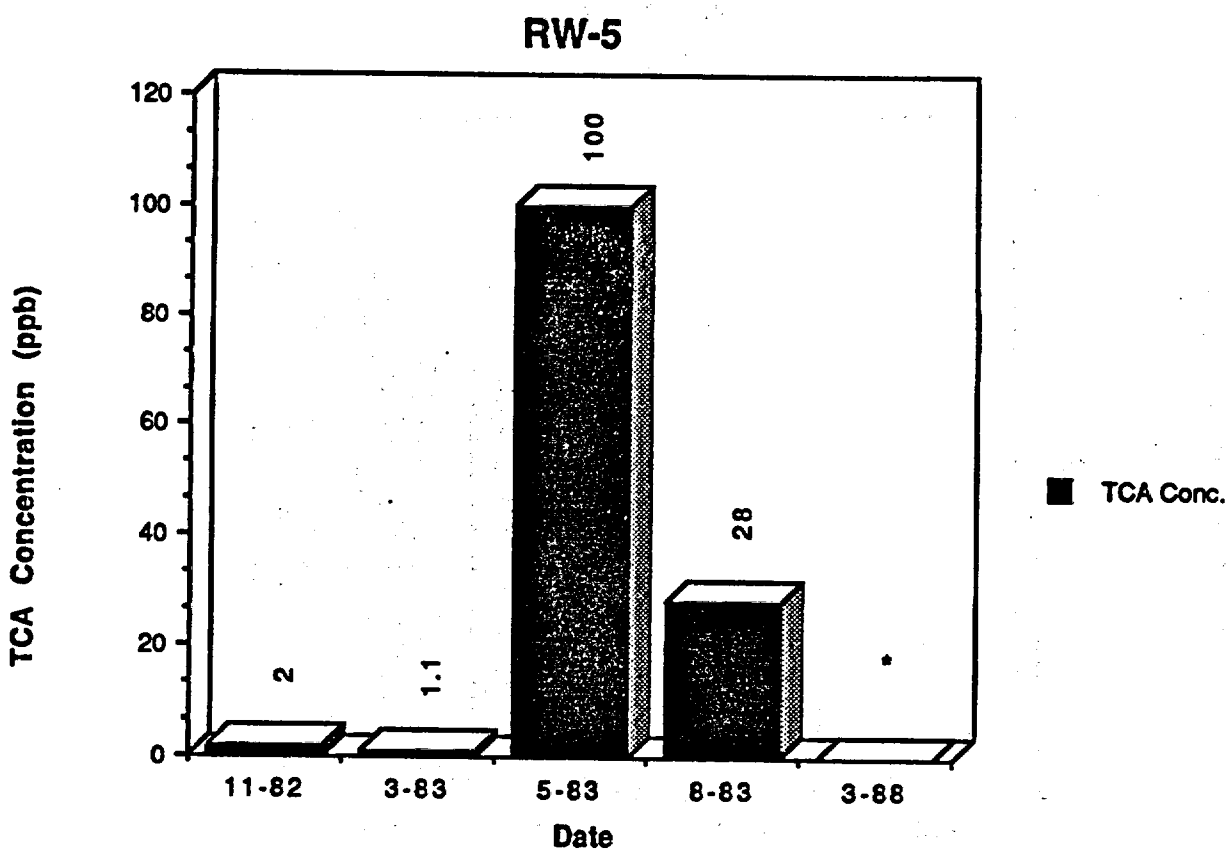
* data for 5-87 did not pass QA/QC procedures

Figure 5-3



* data for 3-88 did not pass QA/QC procedures

Figure 5-4



* data for 3-88 did not pass QA/QC procedures

Figure 5-5

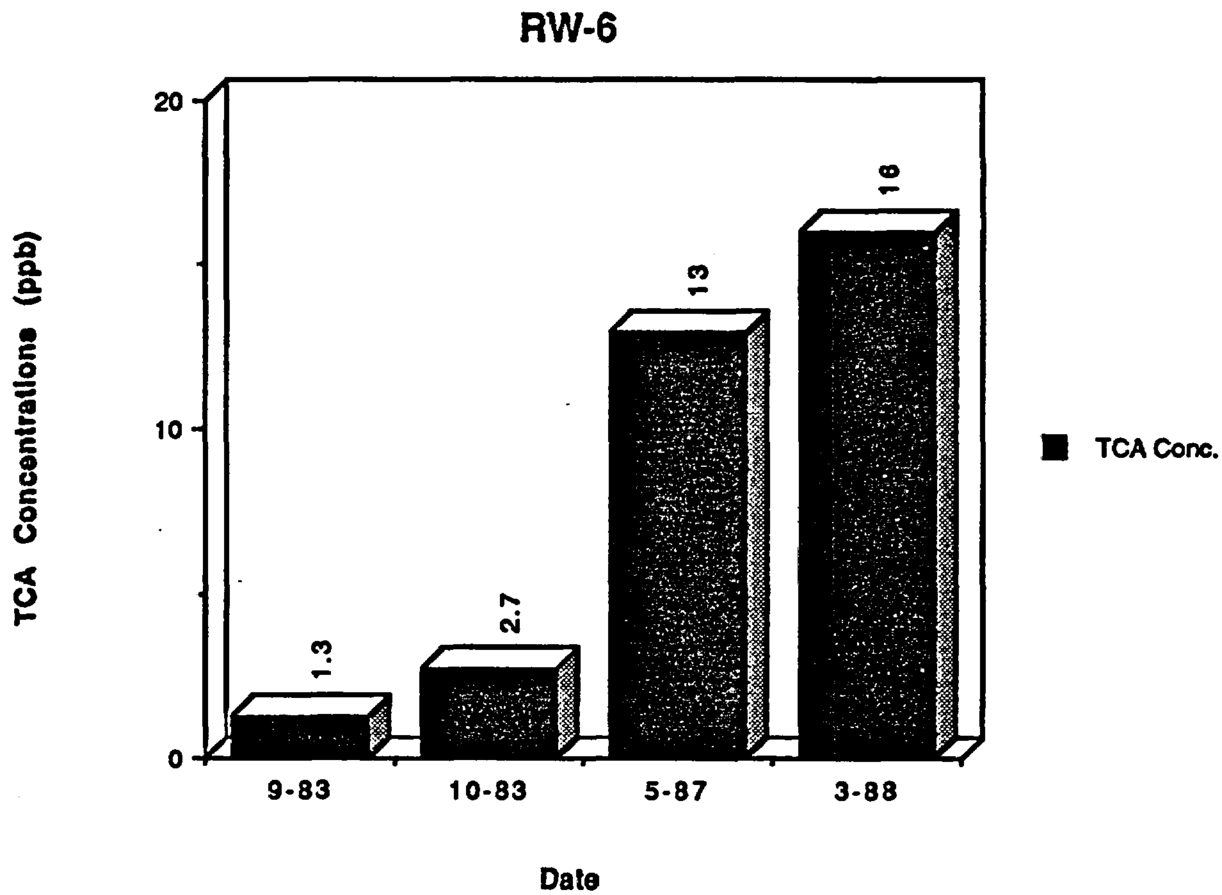
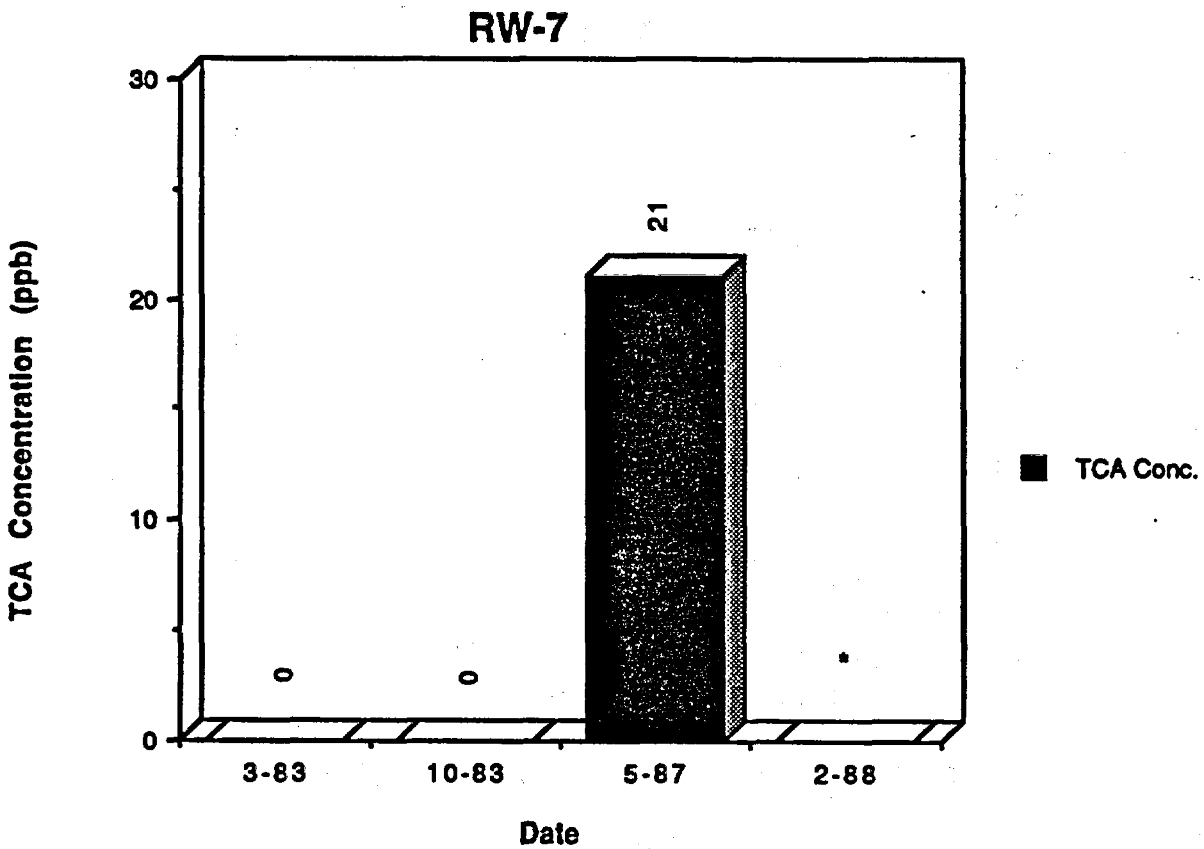
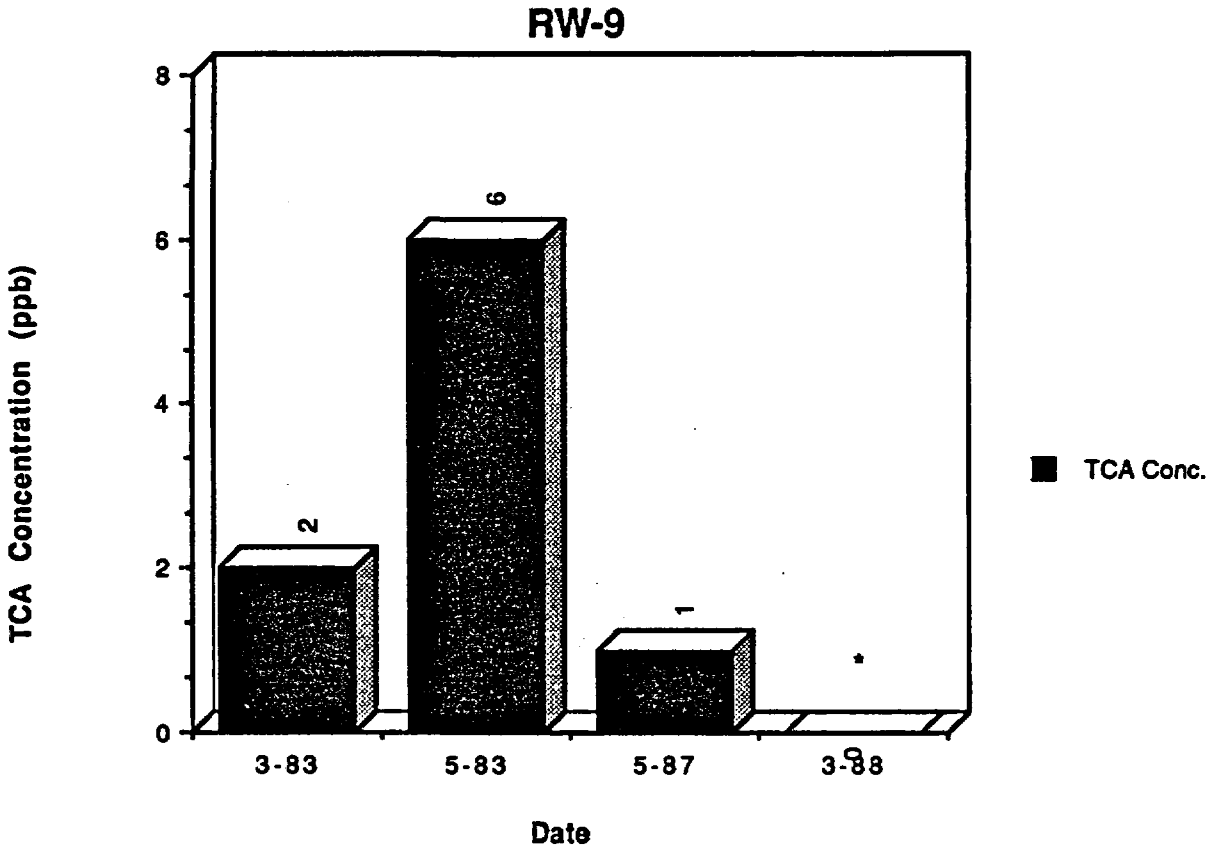

RW-6
20
10
0
TCA Concentrations (ppb)
1.3
2.7
13
16
9-83
10-83
5-87
3-88
Date
TCA Conc.

Figure 5-6



* data for 2-88 did not pass QA/QC procedures

Figure 5-7



* data for 3-88 did not pass QA/QC procedures

Figure 5-8

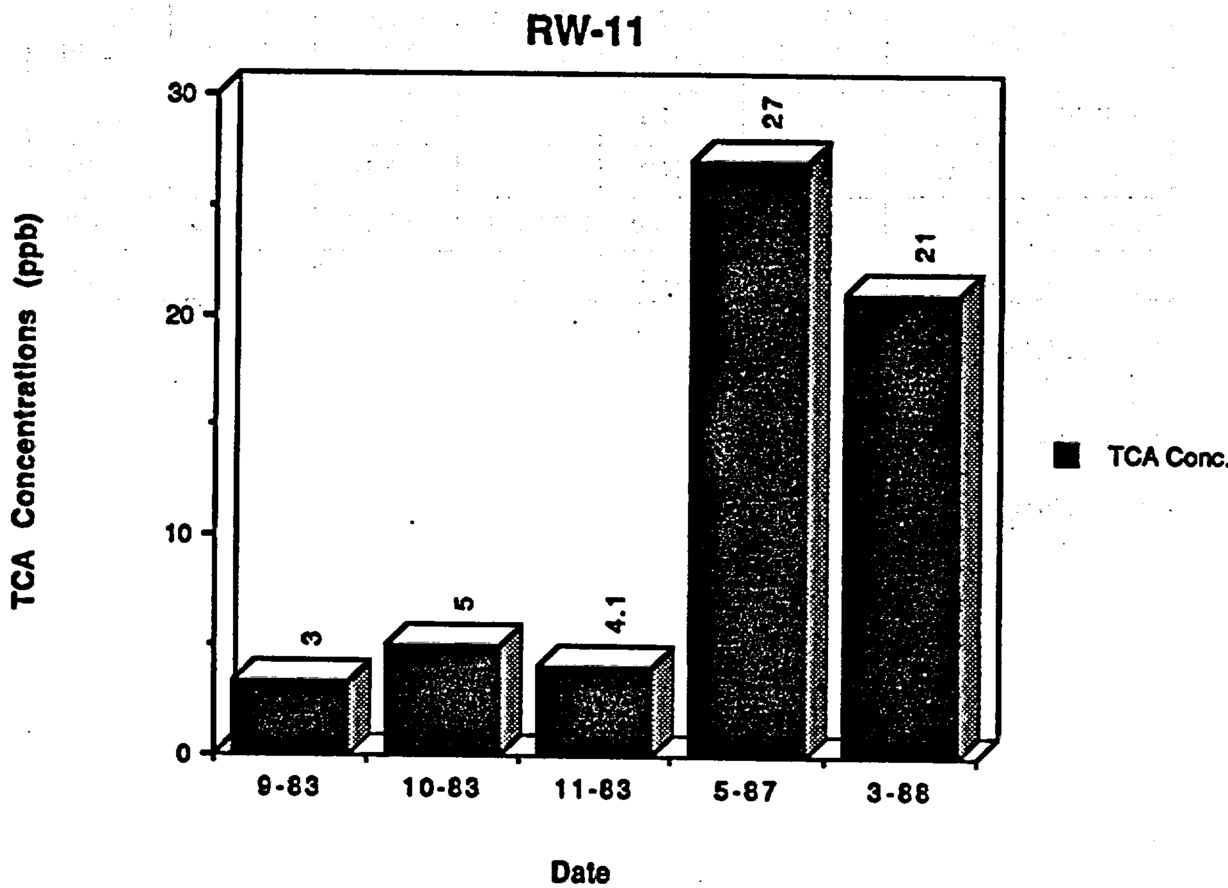

RW-11
TCA Concentrations (ppb)
30
20
10
0
3
5
4.1
27
21
9-83
10-83
11-83
5-87
3-88
Date
TCA Conc.

Table 5-9

SUMMARY OF ANALYTICAL RESULTS FOR SHALLOW MONITORING WELL SAMPLES TAKEN MAY 1987 AND JANUARY 1988 THROUGH MARCH 1988

Chemical	ERT-1 (1987)	ERT-2 (1987)	ERT-3 (1987)	ERT-1 (1988)	ERT-2 (1988)	ERT-3 (1988)
1,1-dichloroethene	ND	ND	*	250.00	*	250.00
1,1-dichloroethane	ND	ND	*	ND	ND	ND
1,1,1-trichloroethane	5.00	19.00	2,900.00	98.00	26.00B	98.00
Tetrachloroethene	ND	ND	ND	ND	ND	6.40

ND - Not detected.
B - Found in blank.

*Data did not pass QA/QC procedures.

All units in µg/l.

at 6.4 µg/l. These concentrations are shown in Table 5-9. Figures 5-9 through 5-11 illustrate the variation in 1,1,1-trichloroethane concentration with time in the ERT wells.

The MW monitoring wells were sampled in November 1987 and again in February 1988 through March 1988 (MW well locations given in Figure 3-5 and Drawing 1). The analytical results for the 1987 sampling round did not pass the QA/QC procedures and will not be discussed here. For the February 1988 through March 1988 sampling round, at least one of the indicator parameters was detected in all of the MW wells as shown in Table 5-10. 1,1-Dichloroethene was detected in all of the MW monitoring wells above the MCL of 7 µg/l. 1,1,1-Trichloroethane was detected in MW-3 through MW-7 and MW-9 above the MCL of 200 µg/l. Additionally, tetrachloroethene was detected in MW-7 at a concentration of 25 µg/l (see Table 5-10).

The SW monitoring wells were sampled in February 1988 through March 1988. The locations of these wells are given in Figure 3-5 and Drawing 1. Wells SW-1 through SW-5 exceeded the respective MCLs for 1,1-dichloroethene and 1,1,1-trichloroethane as shown in Table 5-11. The analytical results for SW-6 and SW-7 did not pass the QA/QC procedures.

5.6.3 Packer Tests

Water samples were taken during the packer tests in October 1987 to give an indication of the vertical extent of contamination. These samples were analyzed for both volatile and semi-volatile organic compounds. Only one packer test sample passed the QA/QC procedures: MW-2 at the 44- to 54-foot depth. This sample showed a 1,1,1-trichloroethane concentration of 19 µg/l.

5.6.4 Summary of Contamination in Groundwater

The primary contamination at the Berks Sand Pit Site occurs in the groundwater. There are four volatile organic compounds that are being used as indicator parameters: 1,1,1-trichloroethane, 1,1-dichloroethane, 1,1-dichloroethene and tetrachloroethene. A review of the historical data indicates that although the contamination at the site has decreased somewhat over the past five years (1983 to 1988), it is still present in significant quantities. The decrease in concentration is probably best illustrated by the hi[illegible] 1,1,1-trichloroethane concentrations recorded for RW-2, RW-3 and ERT-3 (Figures 5-1, 5-2 and 5-11) The historical data, as well as data gathered during this investigation also shows

Figure 5-9

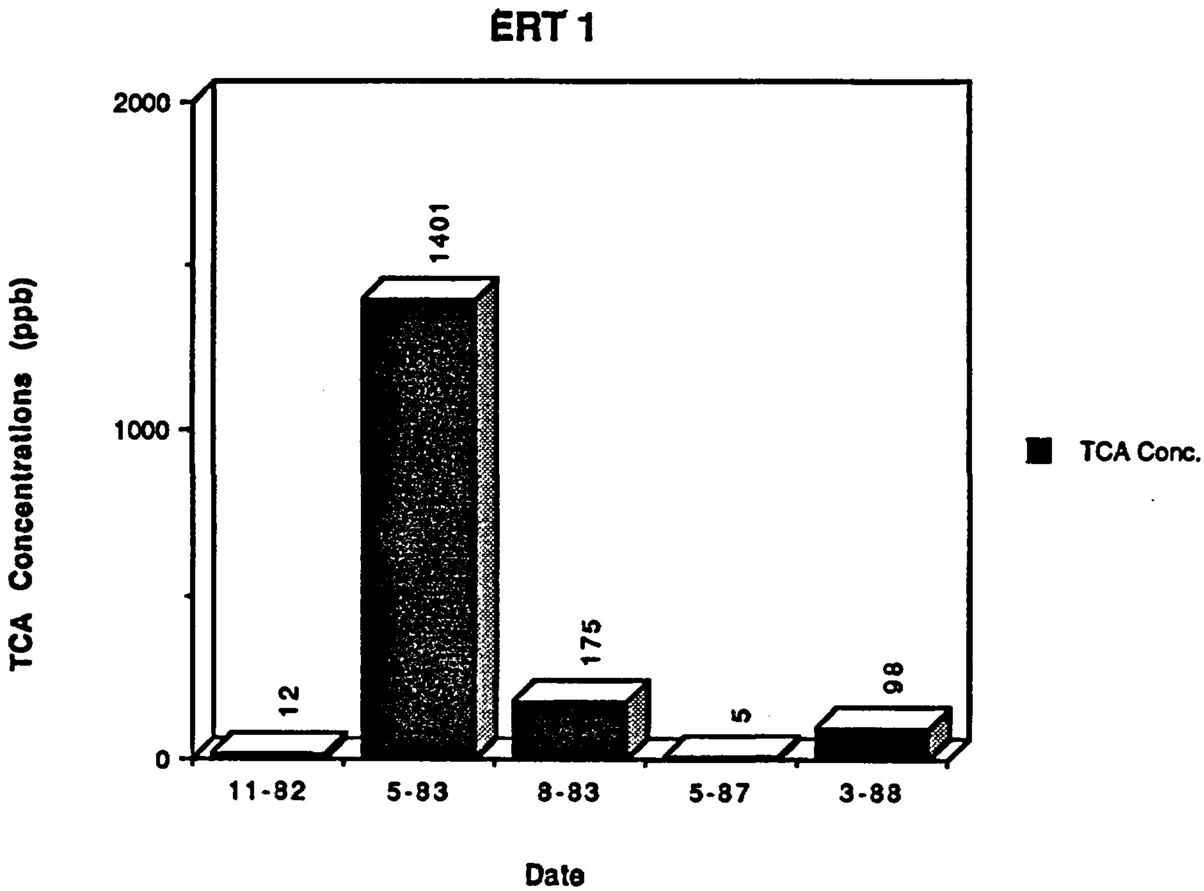
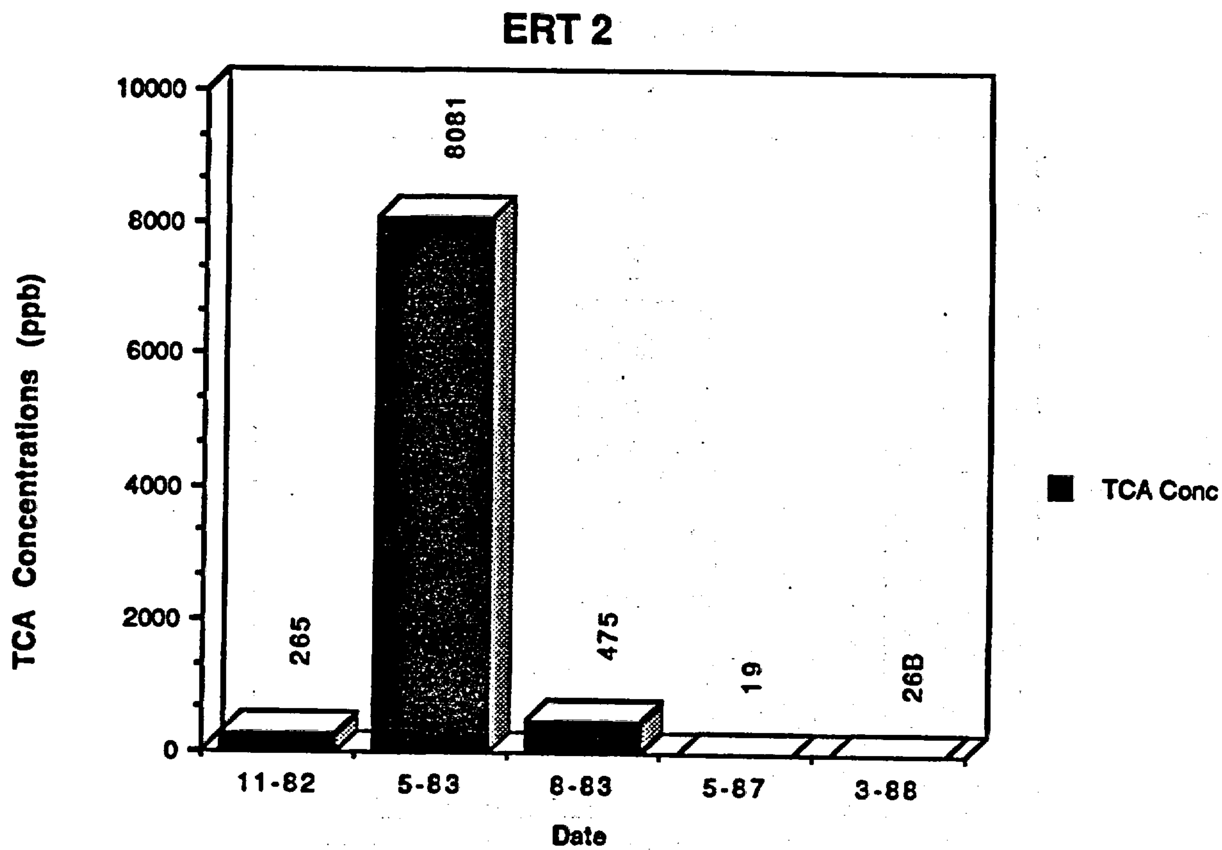

ERT 1
2000
1000
0
TCA Concentrations (ppb)
12
1401
175
5
98
11-82
5-83
8-83
5-87
3-88
Date
TCA Conc.

Figure 5-10



ERT 2
10000
8000
6000
4000
2000
0
TCA Concentrations (ppb)
265
8081
475
19
26B
11-82
5-83
8-83
5-87
3-88
Date
TCA Conc

Figure 5-11

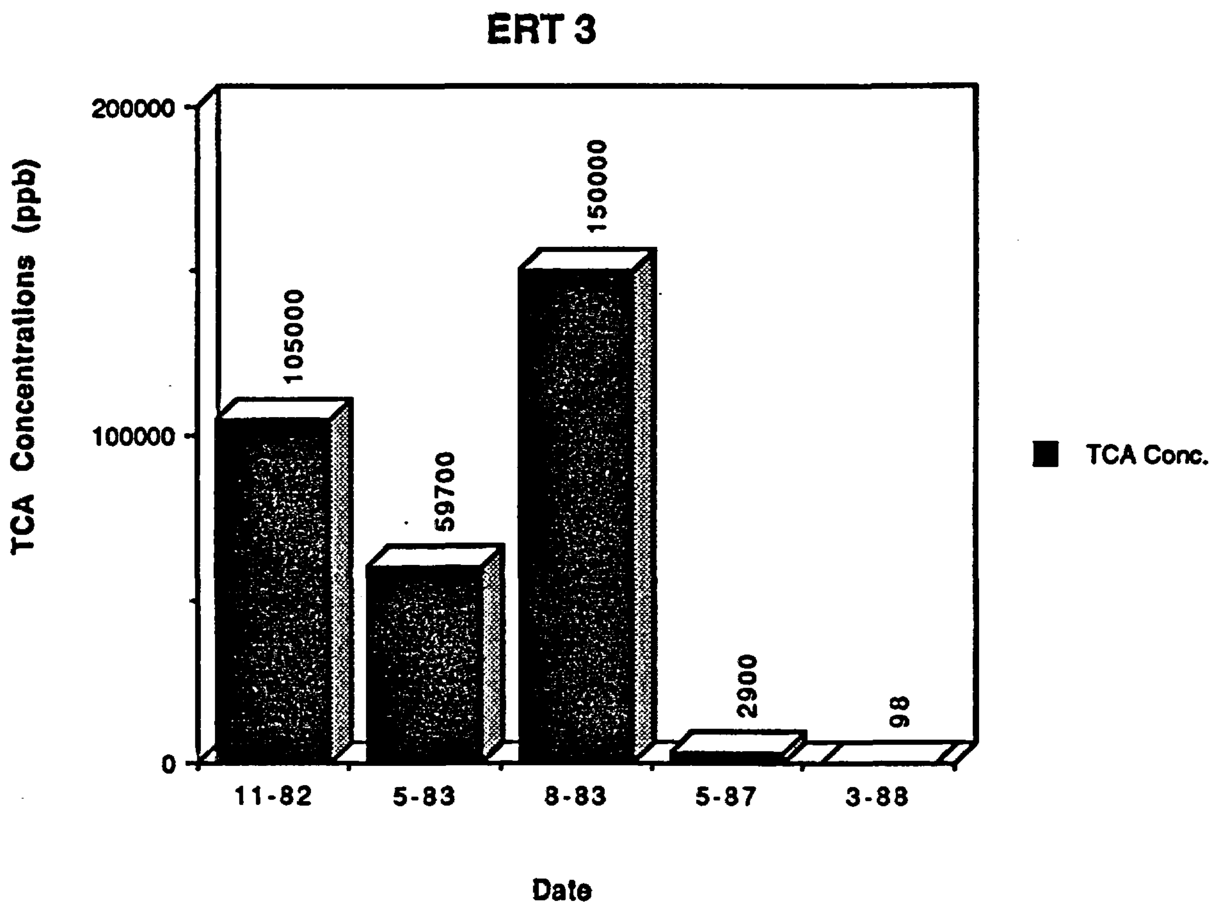

ERT 3
TCA Concentrations (ppb)
200000
100000
0
105000
59700
150000
2900
98
11-82
5-83
8-83
5-87
3-88
Date
TCA Conc.

Table 5-10

SUMMARY OF ANALYTICAL RESULTS FOR DEEP MONITORING WELL SAMPLES
TAKEN JANUARY THROUGH MARCH 1988

Chemical	MW-1	MW-2	MW-3	MW-4	MW-5	MW-6	MW-7	MW-8	MW-9
1,1-dichloroethene	48.00	48.00B	860.00	3,500.00	120.00B	340.00B	1,300.00	41.00B	1,100.00
1,1-dichloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1,1-trichloroethane	180.00B	90.00B	2,200.00B	7,300.00	300.00	940.00	3,700.00	*	3,100.00
Tetrachloroethene	ND	ND	*	*	ND	ND	25.00	ND	*

ND - Not detected.
B - Found in blank.

*Data did not pass QA/QC procedures.

All units in µg/l.

Table 5-11

SUMMARY OF ANALYTICAL RESULTS FOR SHALLOW MONITORING WELL SAMPLES TAKEN JANUARY THROUGH MARCH 1988

Chemical	SW-1	SW-2	SW-3	SW-4	SW-5	SW-6	SW-7
1,1-dichloroethene	850.00	220.00	100.00B	270.00B	280.00	*	ND
1,1-dichloroethane	ND	ND	ND	ND	ND	ND	ND
1,1,1-trichloroethane	1,900.00	6,500.00	240.00	490.00B	600.00	*	ND
Tetrachloroethene	ND	*	ND	*	ND	ND	ND

ND - Not detected.
B - Found in blank.

*Data did not pass QA/QC procedures.

All units in µg/l.

some large fluctuations in 1,1,1-trichloroethane concentrations over relatively short (months) periods of time as illustrated by Figures 5-1, 5-9 and 5-10. Some downgradient residential wells (RW-6, RW-7 and RW-11) also show slightly increasing 1,1,1-trichloroethane concentrations. These time-concentration relationships indicate that the contaminant plume (1,1,1-trichloroethane) is migrating, dispersing and become more dilute with time.

The current extent and direction of movement of contaminants at the site is probably best illustrated by plots of isoconcentration contours for 1,1,1-trichloroethane and 1,1-dichloroethene. Figures 5-12 through 5-15 and Drawings 4 to 7 illustrate the current estimated extent of 1,1,1-trichloroethane and 1,1-dichloroethene concentrations in the shallow (less than 80 feet) and deep aquifers. The contamination in both aquifers appears to be migrating in an east-northeasterly direction.

High levels of 1,1,1-trichloroethane contamination (greater than 1,000 µg/l) in the shallow aquifer extend in an elongated plume from the R-3 property east-northeast at least 900 feet to a tributary of the West Branch of Perkiomen Creek (Figure 5-12 and Drawing 4). The maximum 1,1,1-trichloroethane concentration is centered over SW-2 (6,500 µg/l). The isoconcentration contour plots also were used to estimate the amount of contaminant in the aquifers. The contour plots were planimetered to determine the areal extent of contamination. These areas were then multiplied by a conservative estimate of the saturated thickness (80 feet for the shallow aquifer and 170 feet for the fractured bedrock aquifer) and an assumed representative porosity of 20 percent to obtain an estimate of the volume of contaminated water in each aquifer. These water volumes were multiplied by the appropriate contaminant concentration and conversion factors to yield an estimate of the amount of each contaminant (1,1,1-trichloroethane or 1,1-dichloroethene) in each aquifer in gallons. From Figure 5-12, it was estimated that 100 gallons of 1,1,1-trichloroethane are present in the shallow aquifer.

1,1-Dichloroethene isoconcentration contour plots for the shallow aquifer also were developed (Figure 5-13 and Drawing 5). This plot shows a less elongated contaminant plume centered about SW-4. The upgradient extent of 1,1-dichloroethene contamination is the R-2 property. This plume appears to have a larger lateral extent than the 1,1,1-trichloroethane plume in the shallow aquifer. The estimated amount of 1,1-dichloroethene in the shallow aquifer is 20 gallons.

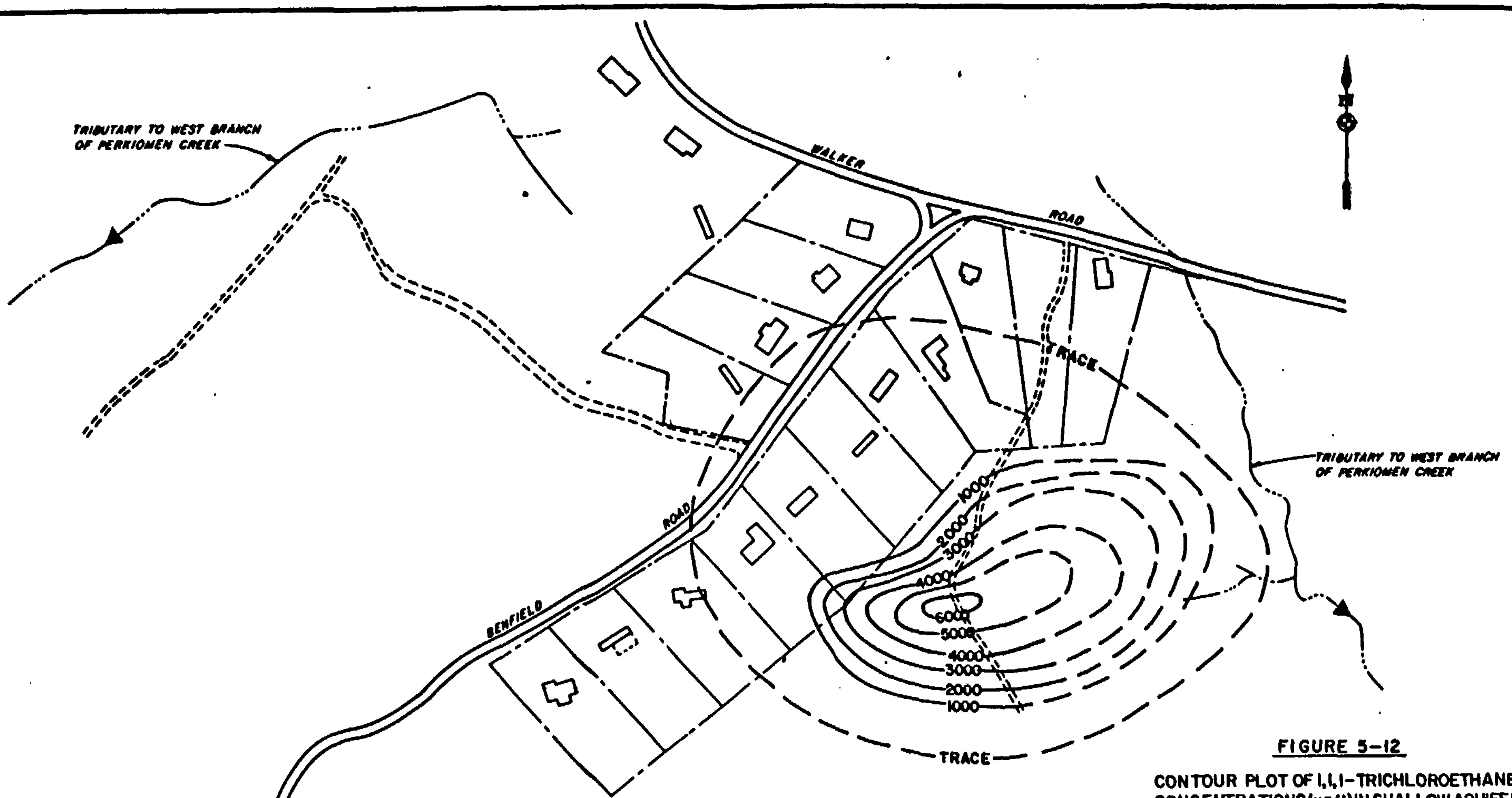


FIGURE 5-12

CONTOUR PLOT OF 1,1,1-TRICHLOROETHANE CONCENTRATIONS (ug/l) IN SHALLOW AQUIFER

——— 1,1,1-TRICHLOROETHANE ISOCONCENTRATION CONTOUR

— — TRACE CONTOUR

NOTES: 1. REFER TO DRAWING 4
2. THE TRACE CONTOUR REPRESENTS THE POSSIBLE EXTENT OF CONTAMINATION ABOVE DETECTION LIMITS. THIS CONTOUR IS ESTIMATED.

BERKS SAND P.I.T.

N.T.S.

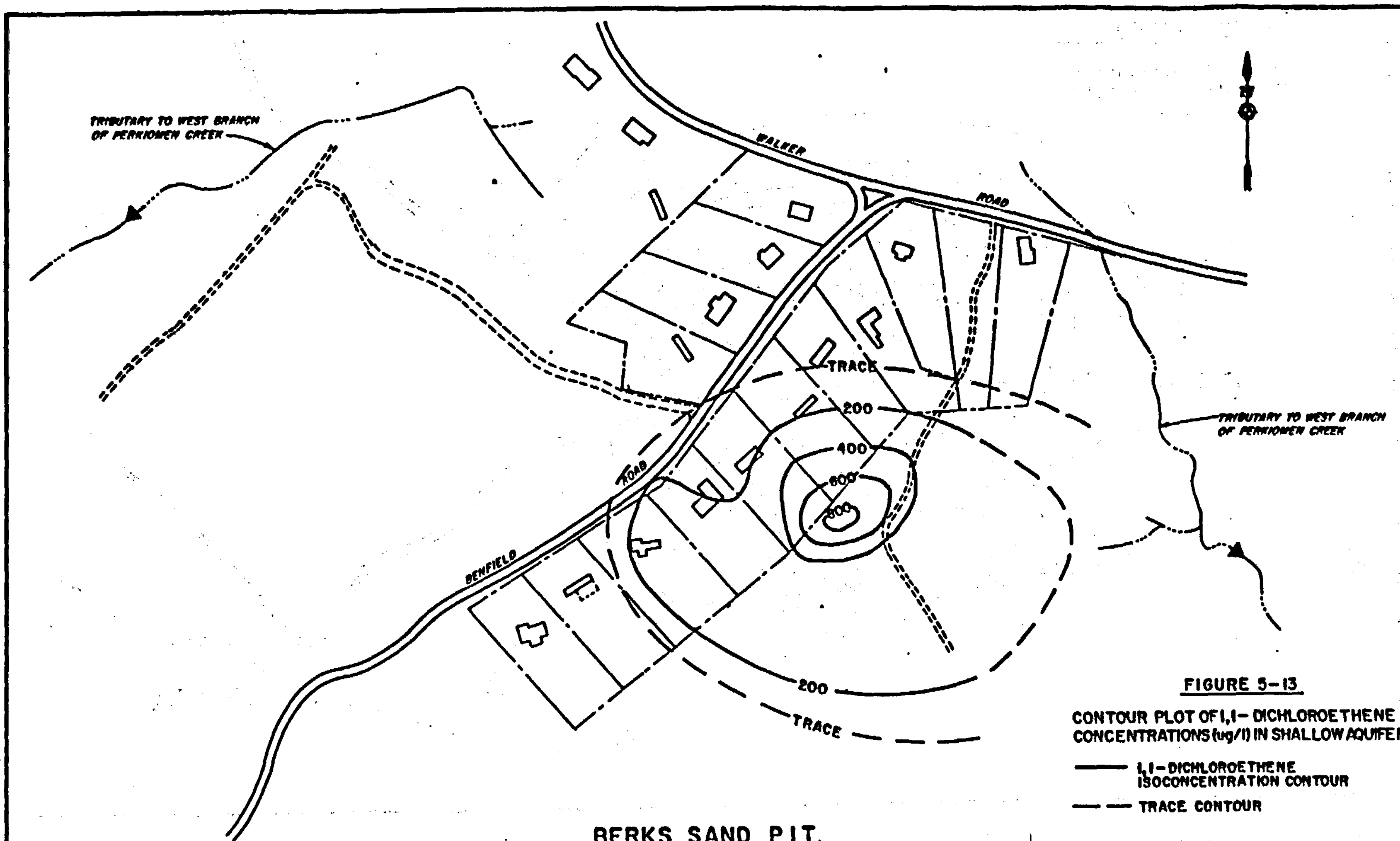


FIGURE 5-13

CONTOUR PLOT OF 1,1- DICHLOROETHENE CONCENTRATIONS (ug/l) IN SHALLOW AQUIFER

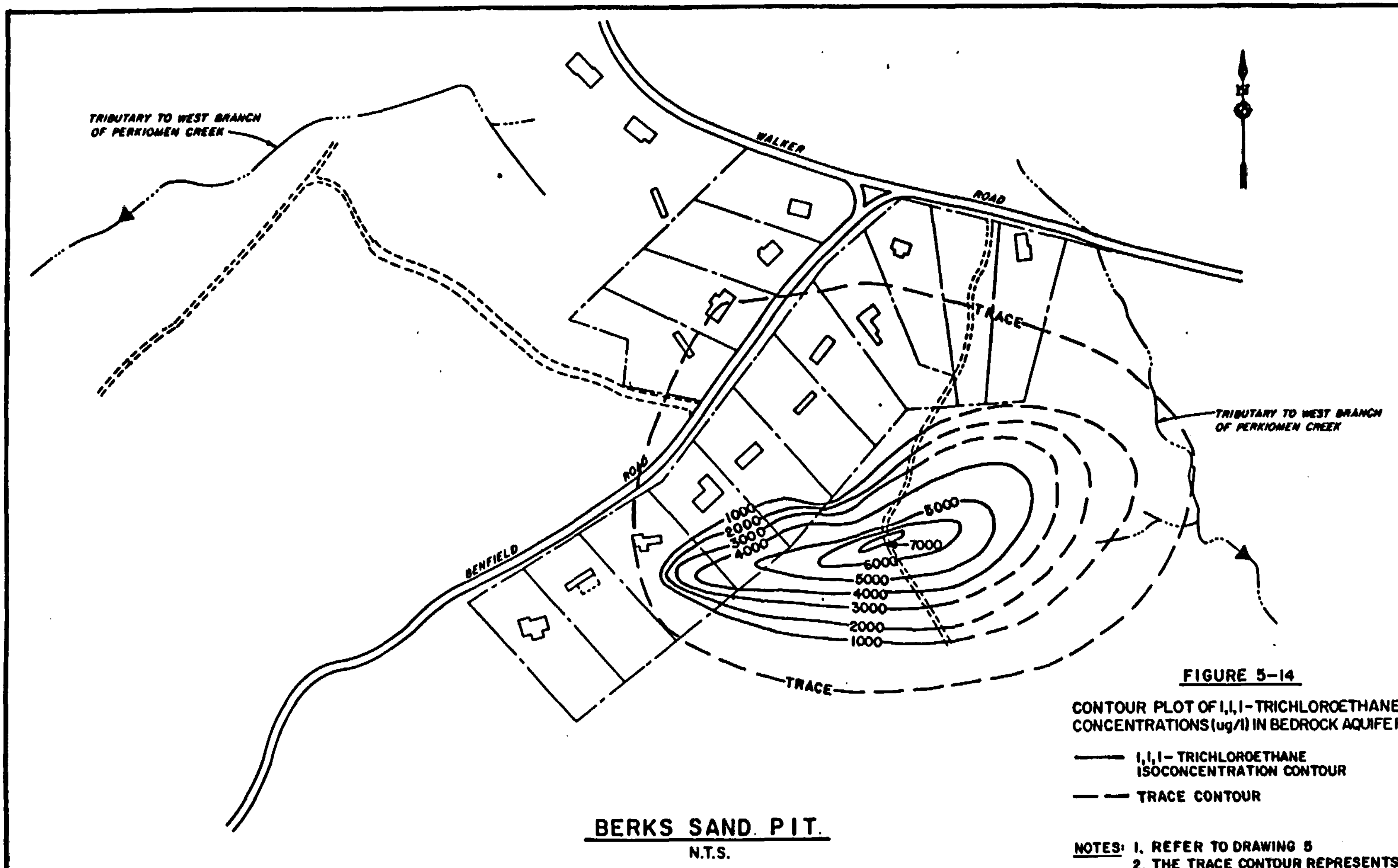
——— 1,1-DICHLOROETHENE ISOCONCENTRATION CONTOUR

— — TRACE CONTOUR

NOTES: 1. REFER TO DRAWING 6
2. THE TRACE CONTOUR REPRESENTS THE POSSIBLE EXTENT OF CONTAMINATION ABOVE DETECTION LIMITS. THIS CONTOUR IS ESTIMATED.

BERKS SAND PIT.

N.T.S.



BERKS SAND PIT.
N.T.S.

FIGURE 5-14

CONTOUR PLOT OF 1,1,1-TRICHLOROETHANE CONCENTRATIONS (ug/l) IN BEDROCK AQUIFER

1,1,1-TRICHLOROETHANE ISOCONCENTRATION CONTOUR

TRACE CONTOUR

NOTES: 1. REFER TO DRAWING 5
2. THE TRACE CONTOUR REPRESENTS THE POSSIBLE EXTENT OF CONTAMINATION ABOVE DETECTION LIMITS. THIS CONTOUR IS ESTIMATED.

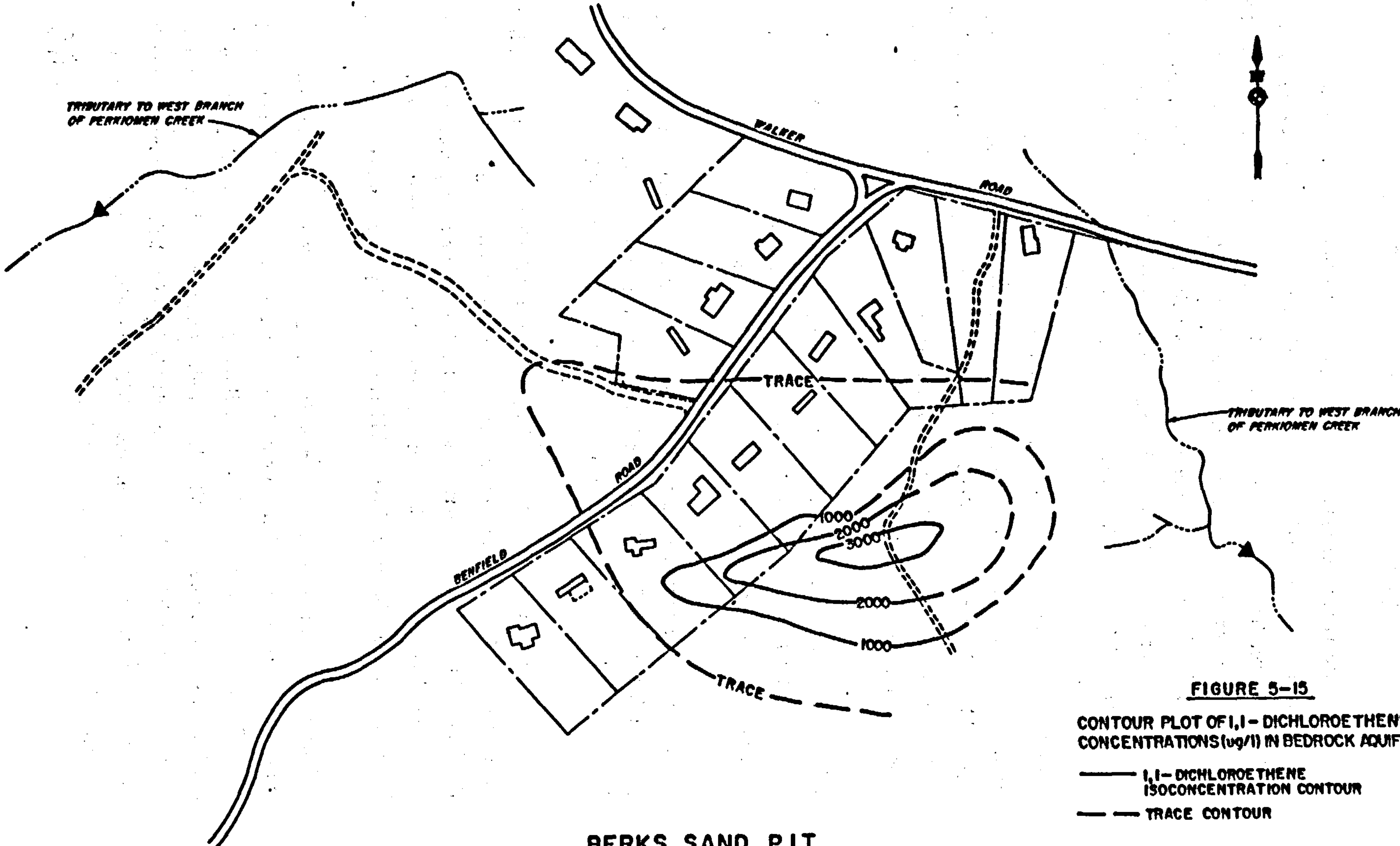


FIGURE 5-15

CONTOUR PLOT OF 1,1-DICHLOROETHENE CONCENTRATIONS (ug/l) IN BEDROCK AQUIFER

——— 1,1-DICHLOROETHENE ISOCONCENTRATION CONTOUR

— — TRACE CONTOUR

BERKS SAND PIT.
N.T.S.

NOTES: 1. REFER TO DRAWING 7
2. THE TRACE CONTOUR REPRESENTS THE POSSIBLE EXTENT OF CONTAMINATION ABOVE DETECTION LIMITS. THIS CONTOUR IS ESTIMATED.

Similar but more pronounced trends are evident in the fractured bedrock aquifer. Figure 5-14 and Drawing 6 show a TCA plume elongated in an east-northeasterly direction. High 1,1,1-trichloroethane concentrations (greater than 1,000 µg/l) extend from the R-2 property east-northeast at least as far as a tributary to the West Branch of Perkiomen Creek. However, the downgradient extent has not been fully defined. The 1,1,1-trichloroethane plume is centered about MW-4 with a maximum concentration of 7,300 µg/l. The estimated amount of 1,1,1-trichloroethane in the fractured bedrock aquifer is 300 gallons.

The 1,1-dichloroethene isoconcentration contour plots for the fractured bedrock aquifer (Figure 5-15 and Drawing 7) follow the trends illustrated by the other plots. Specifically, the 1,1-dichloroethene plume is elongated in an east-northeasterly direction and is centered about MW-4 (3,500 µg/l). The amount of 1,1-dichloroethene in the fractured bedrock aquifer was estimated to be 150 gallons.

All four isoconcentration plots illustrate a similar east-northeast plume elongation. The total amount of 1,1,1-trichloroethane in the system is estimated to be 400 gallons and the total amount of 1,1-dichloroethene is estimated to be 170 gallons.

Lower levels of contamination appear to extend north and northwest of the east-northeast plume axis towards Benfield and Walker Roads. The area of contamination, both high and low, potentially extends into residential properties R-2 through R-12.

The vertical extent of the contamination, investigated during the packer test, has not been fully defined. The contaminants appear to have sunk and/or are being carried to deeper depths within the aquifer by vertical gradients. The maximum depth of contamination, based on the geophysical investigation and the packer tests, is thought to be 250 feet to 300 feet below the surface. However, this should be confirmed by further site investigations.

A definite source area for the contamination at the Berks Sand Pit Site has not been defined. However, the isoconcentration contour plots indicate a source of contamination in the vicinity of the R-2 and R-3 properties. Further soil and groundwater sampling may be necessary to confirm this as a source area. The downgradient and vertical extents of contamination also have not been completely defined. The installation of additional monitoring wells near the expected perimeter of the plume, and within the plume, may help to better define the horizontal and vertical extent of contamination.